THE BIOGEOGRAPHIC DISTRIBUTION OF CADDISFLIES (INSECTA: TRICHOPTERA) WITHIN THE SOUTH-CENTRAL UNITED STATES

Heather A. Perry, M.S.

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APPROVED:

James H. Kennedy, Major Professor
Bruce Hunter, Committee Member
Jeff A. Johnson, Committee Member
Stephen R. Moulton II, Committee Member
Sam Atkinson, Director of the Institute of Applied Science
Arthur Goven, Chair of Department of Biological Sciences
David Holdeman, Dean of the College of Science
Victor Prybutok, Dean of the Toulouse Graduate School

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Through the use of natural history records, published literature, and personal sampling (2011-2016) a total of 454 caddisfly species represented by 24 families and 93 genera were documented from the south-central United States. Two Hydroptilidae species were collected during the 2011-2016 collection efforts that are new to the region: *Hydroptilia scheringi* and *Mayatrichia tuscaloosa*. Eighteen species are endemic and 30 are considered species of concern by either federal or state agencies. The majority of each of these groups is Hydroptilidae, or microcaddisflies. Trichoptera community structure, by minimum number of species, was analysed in conjunction with large-scale geographical factors to determine which factor illustrated caddisfly community structure across the region. Physiographic provinces compared to other geographic factors analyzed best-represented caddisfly communities with a minimum of 10 or more species. Statistically, Hydrologic Unit Code 4 (HUC 4) was the most significant geographical factor but low number of samples representing this variable rendered it less representative of caddisfly community structure for the study area.

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TRADEMARKS

Name	Owner
BEEM® capsules	Better Equipment for Electron Microscopy Inc. 1745 Williamsbridge Road Bronx, NY 10461
5W260 Kawasaki® gas generator	Kawasaki Motors Corp. USA, 26972 Burkbank Foothills Ranch, CA 92610
Olympus® SZ51 & BH-2	Olympus Corporation 3500 Corporate Parkway Center Valley, PA 18034
Optronics Blackeye® Beam Light	Optronics International 401 41St Street East Muskogee, OK 74434
Purell™ hand sanitizer	GOJO Industries 1 GOJO Plz, Suite 500 Akron, OH 44308
Townes style Malaise Insect Trap	Sante Traps 259 Bassett Ave. Lexington, KY 40502

CHAPTER 1

INTRODUCTION

1.1 Statement of Problem

1.1.1 Overview of Caddisflies

Caddisflies (Trichoptera) are a holometabolous order of insects represented by over 14,000 species documented from all the major biogeographic regions with the exception of Antarctica (TWC 2017). The aquatic larvae are found in a wide variety of aquatic habitats and through the use of silk, construct portable cases or fixed retreats with nets using a variety of organic and inorganic materials. The larvae have been widely recognized and admired for their architectural abilities (Wiggins 1996, 2004; Stuart 2000; Stuart and Currie 2002) by artists (Grimaldi and Engel 2005), anglers, naturalists and aquatic entomologists (Ross 1967).

The order name Trichoptera is Greek, *trichos* = hair and *pteron* = wing, in reference to the fine hair (setae) present on the wings of adult caddisflies (Wiggins 2004). They share a common ancestor, Amphinesoptera, with their sister order Lepidoptera (butterflies and moths) (Ross 1967).

1.1.2 Global Status of Caddisflies

The conservation status and the global and ecological importance of caddisflies (Trichoptera) was discussed by de Moor and Ivanov (2008). In their publication they provided baseline data for the global status of caddisflies. At the time the recorded number of extant Trichoptera species was 12,627, with 610 genera and 46 families. It should be noted that there is a discrepancy in their zoogeographic species table due to the usage of published data from the Trichoptera World Checklist (TWC) in 2001 and the unpublished data from TWC in 2006 with the number of recorded species in this five-year gap increasing by 1,095 or 9.5%. The greatest Trichoptera speciation occurs within the Oriental (3,723) and Neotropical (2,100) regions, while the lowest number of recorded species is from the Afrotropical region (944). The Holarctic (Palearctic and Nearctic regions combined) totals 3,910 species with 1,461 of those species reported from the Nearctic. Of the 45 extant families, 5 contain over 50% of the known species and of the 620 extant genera, 10 make up 29% of Trichoptera species. Since the publication of de Moor and Ivanov's paper the number of known caddisflies is now reported to be 14,548 species, with 616 genera and 49 families (TWC 2017), which is an increase of 15% (1,921 species) in 9 years.

It is estimated that only 20-25% of the world species of Trichoptera have been described and that the number of species could be as high as 50,000. While the discovery of new species continues, adding to the biodiversity of global caddisflies, information concerning endemic species becomes ever more important in understanding their diversity. The highest level of endemism is in the Australian region, which has six endemic families and 120 endemic genera/sub-genera; other regions have a high level of either endemic families or endemic genera (de Moor and Ivanov 2008). Endemic species are of particular concern when their geographic range is restricted; Hering et al. (2009) modeled caddisfly distributions in Europe and proposed that endemic species occurring in a large ecoregion would be less susceptible to climate affects than endemic species relegated to smaller geographic ranges.

In an effort to understand the implications of the decline in the Earth's biodiversity the International Union for the Conservation of Nature (IUCN) began documenting the world's species conservation status (e.g. no known status, threatened, extinct etc.) in the late 1990s (IUCN 2017a). The IUCN Red List for Class Insecta has evaluated approximately 7,100 insect species for degree of threatened status. However, if the Class Insecta is divided into terrestrial versus aquatic species evaluated, 46% of the species evaluated are aquatic. Of the 3,241 aquatic species on the Red List, 98.9% are within one order, Odonata (3,208 species), and the remaining 33 species represent Ephemeroptera, Plecoptera, Trichoptera, and Coleoptera (Dytiscidae)(IUCN 2017b).

The order Trichoptera is the seventh largest aquatic insect order but only four species have been assessed by the IUCN and all are presumed extinct. Three of species are from The United States and are *Rhyacophila amabilis* (Rhyacophilidae), *Triaenodes phalacris* and *T. tridonata* (Leptoceridae) with the remaining species from Germany, *Hydropsyche tobiasi* (Hydropsychidae) (IUCN 2017c). As mentioned above in addition to Trichoptera, the only other aquatic orders evaluated by the IUCN were Ephemeroptera, Plecoptera, and Coleoptera (Dytiscidae) with three, four, and 22 evaluated species, respectively (IUCN 2017c). It is apparent that much more work needs to be done on the status of many of the freshwater benthic macroinvertebrates, especially Ephemeroptera, Plecoptera and Trichoptera due to their importance in the transfer of energy within freshwater habitats and the surrounding terrestrial habitat (Huryn et al. 2008).

Questions concerning habitat loss, climate change, in-stream water flow etc. are important factors in deciding the fate of a species through global efforts being undertaken by the IUCN and the Global Biodiversity Information Facility (GBIF). Biological diversity is unevenly distributed on a global scale, and therefore conservation responses should be prioritized to minimize potential biodiversity loss (Brooks et al. 2006). Compared to other faunal groups invertebrates are under represented in global conservation initiatives, additionally conservation lags behind for freshwater ecosystems (Houghton 2012, Brooks et al. 2006). Documenting the biodiversity for aquatic insects is important due to their utilization in water quality biomonitoring (Houghton 2012).

Establishing baseline caddisfly biodiversity in the south-central United States was initiated due to the importance of caddisflies as generally pollution intolerant indicator species in biological monitoring, impacts upon stream nutrient cycling, energy transfer within both aquatic and terrestrial habitats, and as potential indicators for climate change (e.g. range extensions or contractions). In order to answer broad scale questions concerning species ranking, baseline data are needed to determine distributions and habitat requirements. In an effort to understand the factors that influence the distribution of caddisflies within the south-central United States this study evaluated several broad scale geographic factors: physiographic regions, ecoregion, hydrologic unit code (HUC), and average annual precipitation to determine which variable was most suitable in assessing species community structure. This region of the United States lies at the intersection of five physiographic divisions (USGS 2015a), and is the most westerly extension of the Atlantic Plain; most southerly reach of the Interior Highlands, the Great Plain, Intermontane Plateau and the Rocky Mountains. This culmination of these physiographic divisions, and therefore the finer scales of physiographic provinces and sections, lends itself to caddisfly species biodiversity that expands to a majority of the continental United States. Neotropical families, genera, and species have been documented from southern parts of the study area due to its proximity to Mexico and Central and South America.

1.2 Objectives and Hypotheses of Study

1.2.1 Objectives

1. Inventory of the caddisflies of the south-central United States through the use of natural history collections (NHC), published literature, and personal sampling to determine distributional patterns of caddisflies.

   1.a Determine if NHC records can be utilized as an effective tool in biodiversity studies.

2. Evaluate the influence of broad scale geographic factors in conjunction with a minimum number of caddisfly species to evaluate which community structure and geographical factor best represents biogeographic patterns in caddisflies.

1.2.2 Null Hypotheses

1. Caddisfly communities will not differ by minimum number of species present by geographical variables.
2. Caddisfly communities in the south-central United States are not distributed along precipitation gradients.
3. Caddisfly communities will not differ within the south-central United States based on established biotic provinces or ecoregion.
4. Caddisfly communities will not differ by hydrologic unit code 4 (HUC 4).
5. Sampling locations will not be biased by physiographic section.

1.3 Scope

There are several extensive caddisfly biodiversity surveys from the United States, but most were done during the early 20th century and often over a limited geographical area (i.e. state or mountain range). Peer reviewed literature on aquatic invertebrates, including Trichoptera, are often geographically biased with publications heavily skewed towards North America and Europe (Contador et al. 2012, Dudgeon et al. 2006). Furthermore, biodiversity studies are often conducted within the construct of political boundaries (e.g. state, county, park etc.), or some other predefined location (e.g. watershed, forest etc.). Previously published accounts of caddisfly taxonomic surveys from the south-central United States include scenic and highly diverse regions such as Big Bend, The Big Thicket, the Texas Hill Country, and the Ozark Mountains. These areas are characterized as being biological “hotspots” or areas with charismatic features (e.g. springs, Neotropical flora). For the south-central United States these “hotspots” are often associated with a change in broad landscape physiographic features (e.g. mountains, plains etc.). In contrast, other regions such as the Texas Panhandle and the arid southwest are under represented for caddisflies in comparison. Habitat availability is the most likely explanation for these areas being under surveyed. The permanence of water is of particular interest when studying organisms whose life cycle is dependent on the availability of water. Areas in the Panhandle and the arid western region of the study area receive less than 20 inches of average annual precipitation; so permanent water bodies are often ephemeral in nature in areas such as this.

1.4 Contents of Remaining Chapters

Chapter 2 provides a background and review of relevant literature and discusses the importance of natural history collections. Chapter 3 describes the study area, acquisition of natural history records, methodology used to sample caddisflies, geographical factor selection, processing and identification of caddisflies, and statistical analyses. Chapter 4 provides the results for historical natural history collections; records obtained from published literature accounts; endemism; species of concern; Heather A. Perry sampling results; caddisfly demographics; new species records; statistical analyses to determine biogeographic region structure, minimum number of caddisfly species for community structure, sampling location bias, community structure similarity and dissimilarity. Chapter 5 provides review of species distribution relative to physiographic features and discusses biogeographic factors that have influenced distribution of caddisfly species in the south-central United States.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a literature review on general caddisfly biology and ecology (Section 2.1), previous taxonomic work on caddisflies with particular attention to the south-central United States (Section 2.2-2.3) and the significance of natural history collections in this study (Section 2.4).

2.1 Trichoptera Literature Review

2.1.1 Biology of Caddisflies

The general morphology of caddis larvae includes a sclerotized, external head; small peg-like antennae that may not be visible in some families; eyes that are formed by a group of stemmata; mandibles with a series of teeth or scraping edge; labium where silk is emitted through a small opening termed the spinneret (Wiggins 2004, Wiggins and Currie 2008, Morse 2009); and are apneustic (Ross 1967). Trichopteran life cycles typically include 5 instars (Wiggins 1996) with development being dependent upon accumulated degree-days (Pedigo and Zeiss 1996) but with changing temperatures the number of generations could be altered per year (Wiggins 1996, Wiggins and Currie 2008). However, climate factors are dependent upon location. A study by Huamantinco and Nessimian (2000) in the Paquequer River in southeastern Brazil on Trichopteran life history patterns found that adult emergence coincided with the rainy season. This finding is supported by other studies done in South America by Oliveria (1996) and Flint (1991) who also documented adult emergence after rain events.

While most caddis larvae exhibit an aquatic existence there are some that have incorporated the use of terrestrial habitats as part of their life history strategy. Many larvae that have evolved unique life history methods belong to the family Limnephilidae. Several limniphilid species *Enoicyla pusilla*, *Philocasca dernita, Caloca saneva* and *Architremma ulachensis,* and *Ironquia parvula* (Flint 1958, Erman 1981, Levanidova and Vshivkova 1984) undergo some degree of development on land. Nocturnal migration is known in *Desmona bethula,* which leave their aquatic habitat in order to feed upon emergent aquatic and semiaquatic plants (Erman 1981). Solely terrestrial life history strategies are known for three species of European *Eniocyla*, where all life stages inhabit forest floor leaf liter (Chuluunbat et al. 2010). One Japanese species of *Nothopsyche* has a completely terrestrial existence while other Asian species of this genus are adapted to ephemeral aquatic habitats and aestivate on land prior to pupation and adult emergence (Chuluunbat et al. 2010). Egg masses are laid by some species of *Limnephilus* in dry basins of temporary pools where the larvae remain within a gelatinous egg mass until ponds are inundated with water (Erman 1981).

Examples of other families that utilize terrestrial habitats include a Tasmanian Calocidae species, which inhabits moss and moist leaf liter in wet forests (Erman 1981, Holzenthal 2007), and the Apataniidae genus *Manopylax* known from North America and Japan (Chuluunbat 2010). Five species of *Manopylax* larvae possess no gills and inhabit moist, terrestrial rocks where they feed on algae and diatoms. An additional North American species of this genus has gills but occupies habitat in a thin layer of water covering the surface of rocks (Chuluunbat 2010).

Philanisus plebeius (Chatamiidae) is an Australian caddisfly that oviposit eggs in the papular pores of the intertidal starfish, *Patiriella regularis*. Upon hatching the 1st instars leave the starfish through the same pores and construct cases of calcareous algae. The larvae inhabit marine, intertidal rock pools, where they feed upon Rhodphycae "red algae" (Winterbourn and Anderson 1980, Holzenthal 2007).

Since pupation in most Trichopteran families occurs in an aquatic environment, pupae have several morphological features that allow for respiration within the cocoon and aid in emergence at the waters surface. They are capable of movement, which allows them to undulate moving water through their cocoons for respiration. Hook-plates are present on abdominal segment and attach to the silken cocoon to aid in movement of the pupae. These plates differ in shape and position on the abdomen among families and are used for pupal identification. Mandibles, except for some Phyryganeidae, are stout and sclerotized. Some are blade like or have serrated edges for cutting through the pupal enclosure (Wiggins 2004, Wiggins and Currie 2008).

Once free from the cocoon the pupa swims to the waters surface where the adult emerges from the pupal exoskeleton (Wiggins 1996). Adult Trichoptera are pale grey to brown, but there are some with distinctive patterns on their forewings such as *Macrostemum carolina* (Hydropsychidae) (Ross 1944, Moulton and Stewart 1996), *Hydatophylax argus* (Limnephilidae) and *Oligostomis pardalis* (Phryganeidae). Distinguishing morphological characteristics such as setal warts, number of segments on the maxillary palps, the terminal end of the maxillary palps, and the tibial spurs are used to identify caddis adults to family/genera as well as an aid to distinguish the sexes (Wiggins and Currie 2008). Male genitalia morphology is used to identify most adults to species. Adults possess two pairs of wings that are covered in fine hairs, a pair of antennae, and have the ability to feed through modified mouthparts called a haustellum (Ross 1944, Grimaldi and Engel 2005) that is comprised of a fused hypophyarnx and prelabium forming a channel through which liquid food can flow (Ross 1967, Grimaldi and Engel 2005, Gorth 2011).

Adult caddisfly communication is done through the use of pheromones, visual cues and vibrational signals (Ivanov 1993). Females produce pheromones in glands on the venter of abdominal segments 4 and 5 and males use these pheromones to locate receptive females. Visual cues are used by both sexes in a few families. For example, Phryganeidae and Odontoceridae males cue in on female wing posturing as a sign of her readiness for mating as well as a signal of submission between males engaged in courtship battles. Several forms of vibrational cues serve as a signal for mating or stimulation prior to mating including: 1) sexes exchange vibrational cues prior to mating in the form of scraping and knocking or tapping, 2) females may drum prior to copulation as a signal of readiness, 3) male roaring as a symbol of aggression, 4) body trembling by males to stimulate females, and 5) beating of the wings on the ground prior to copulation (Ivanov 1993).

Once copulation has occurred gravid females set out to lay their egg masses in suitable habitats. Eggs are laid within a sticky, polysaccharide called spumalin forming a gelatinous egg mass (Morse 2009), which can contain a few dozen to over 700 eggs (Hinton 1981b). There are two types of common caddisfly egg masses. The most common is the “jelly-like” water-absorbing spumalin that swells to several times its original size after immersion in water (e.g. Limnephilidae, Phryganeidae, Leptoceridae etc.) (Hinton 1981b, Balduf 1939). This gelatinous egg mass can be oval (*Limnephilus lunatus*), horse-shoe (*Agrypnia picta*), or a complete ring (*Phryganea striata*) (Hinton 1981a). Disc shaped egg masses found in families such as Hydropsychidae, Philopotamidae and Psychomyiidae contain very little spumalin and are cemented to the substrate (Hinton 1981a, b). Egg positioning in egg masses may be parallel (low spumalin mass) or layered one on top of the other (high spumalin mass) (Bandulf 1939, Hinton 1981b).

Egg mass placement is often under the water's surface (e.g. Hydroptilidae and Phryganeidae) or on over hanging vegetation above a stream or pond (e.g. Limnephilidae). *Discosmoecus atripes* (Limnephilidae) deposit their egg masses partly in and partly out of the water, while other Limnephilidae such as *Limnephilus indivisus*, lay their eggs in woody debris in temporary ponds where the larvae hatch within the spumalin but do not escape until water returns (Hinton 1981a). One species, *Rhyacophila nubila,* is reported as laying its eggs individually or in small groups in the crevices of submerged woody debris (Hinton 1981b).

2.1.2 Ecology of Caddisflies

Caddis larvae utilize a broad scope of food resources and have many adaptations to feed across all functional feeding groups (FFG) (i.e. shredders, collectors, scrapers and predators); this system of classifying aquatic benthic invertebrates was established by Cummins and Klug (1973, 1979) and uses both morphological and behavioral feeding characteristics to assign organisms into FFG. One of the most well understood uses of silk is associated with the filtering of food from the water column. Net-spinning caddis larvae (e.g. Hydropsychidae and Philopotamidae) use silk to spin a fixed retreat where the larvae retrieve food particles filtered from the water column by the silken net (Cummins 1973, Mackay 1979, Wiggins 1996). Partitioning of food resources occurs as a result of the construction of silken nets with different mesh sizes that sieve different particle sizes from the water column. The partitioning of food based on particle size ingested by instars allows multiple age ranges (both inter and intra species) to occupy the same stream without competing directly for food resources (Cummins 1973, Wiggins 1996). In several cases caddisfly larvae can be associated with multiple FFG depending upon instar feeding capabilities (Cummins 1973, Wiggins 1996). Ramirez and Gutiérrez-Fonseca make the case for using both morphological and gut content analyses for FFG assignments (2014). They analyzed gut contents of Hydropsychidae larvae, which are classically described as filterers, having diets primarily consisting of animals (e.g. Chrionomidae) and therefore should be placed in the tropic guild of predators.

2.1.3 Evolution of Caddisflies

The following discussion of caddisfly evolution is based on reviews by the following authors Ross (1967), Wiggins (2004) and Wiggins and Currie (2008). Insects appear in the fossil record ~400 million years ago (mya), and the ancestor of trichopterans and lepidopterans, Amphiesmenoptera, were present during the Permian period around 295-250 mya. Trichopteran larvae were successful in invading aquatic ecosystems, while lepidopterans continued with a terrestrial existence as caterpillars. The ancestor between these two lines is believed to have had an adult form similar to the present caddisfly adult, while the larvae were more similar to the caterpillars we now associate with lepidopterans. Once the lineage to the caddisflies began to diverge the adults remained relatively the same while the larvae became highly modified for an aquatic life.

The origins of trichopterans began ~250-200 mya during the Triassic period (Ross 1967, Morse 1997, Wiggins 2004, de Moor and Ivanov 2008). The breakup of Pangea (~150 mya) during the Jurassic period, into Laurasia and Gondwana and the subsequent breakup of those continents into smaller landmasses, led to the current distribution of extant families (Ross 1967, Wiggins 2004, de Moor and Ivanov 2008). Fossil records of extinct caddisflies are known from early Jurassic wing fossils, but extant suborders are known from wing and portable case fossils from the middle to late Jurassic period (~150-135 mya) (Wiggins 2004).

2.2 Faunal Studies of Caddisflies in North America

The beginning of large-scale, or state focused, faunal studies of caddisflies in North America began with the publication of Betten's (1934) *The Trichoptera or Caddisflies of New York State.* H.H. Ross's 1944 publication of *The Caddis Flies, or Trichoptera, of Illinois* sets out to include not only a checklist of the caddisfly fauna of Illinois but also provided information concerning their biology, habitat preference, distribution, as well as collecting and preservation techniques. The most significant aspect of Ross's publication is the family key that provided identification of the larvae, pupae and adult caddisflies. Further taxonomic keys provided allow the user to identify larvae to genera and in some instances to species, pupae to genera, and adults to genera and species. Each species key is followed by a brief description of the species as well as specific distribution information. Ross's work was not limited to species only reported from Illinois, but included species that had broader distributions. Denning in Usinger's *Aquatic Insects of California* (1956) provided a short synopsis of the known number of species from California as well as keys to larvae and adults. North American caddisfly taxonomic works by Wiggins (1996, 2004) provide ecological and evolutionary background as well as family keys to larvae, pupae, and adults.

2.3 Previous Trichoptera Taxonomic Works from the South-Central United States

Prior to the publication by Moulton and Stewart (1996) most caddisflies were documented from the south-central United States from published species checklists. Species checklists often provided only a listing of species for a given geographical location with some providing local information on habitat requirements.

2.3.1 Arkansas

Unzicker et al. (1970) documented 105 species in their preliminary caddisfly species of Arkansas checklist. Records were primarily concentrated around Fayetteville located in the Ozark Plateau. Collaboration between H.W. Robinson, J. Unzicker, S. Harris, and B. Armitage in the 1970s attempted statewide documentation of Arkansas caddisflies but was discarded after the 1989 publication of Bowles and Mathis's checklist inventoried 153 species from the mountainous regions of Arkansas (Moulton and Stewart 1996). Moulton and Stewart catalogued 229 species in their 1996 publication *Caddisflies (Trichoptera) of the Interior Highlands of North America* based on physiographic regions covering the Ozark, Ouachita, Arbuckle and Wichita Mountains. While this study included a detailed checklist, brief family descriptions, genera and species keys, and detailed species accounts that included type locality, regional distribution, Nearctic distribution, and illustrations for each species it also incorporated statistical methods to evaluate hypotheses to determine the geographic factors that influenced caddisfly distribution on a large geographical scale (e.g. latitude and geology). It is the later point that separates this study from the other species checklists.

2.3.2 Louisiana

S.C. Harris, P.K. Lago, and R.W. Holzenthal (1982) published a three part series documenting the caddisfly species of Mississippi and southeastern Louisiana. Each publication focused on one of the three following superfamilies: Hydropsychoidea, Rhyacophiloidae, and Limnephiloidae. Of the 139 species documented from this study, 66 were from southeastern Louisiana (Hydropsychoidae = 23, Rhacophiloidea = 14, Limnephiloidea = 29). This survey of Louisiana included only 8 (12.5%) of the 64 parishes in the state. Morse and Barr (1990) documented 43 species of caddisflies from Schoolhouse Springs in Jackson Parish, located in north-central Louisiana. The springs were purchased by the Louisiana Nature Conservancy in 1988 and designated a preserve due to the unique aquatic biota.

2.3.3 New Mexico

In 1983, Waltz and McCafferty published a list of 12 new caddisfly records for

New Mexico. D. Ruiter (1995 un-published) presented a preliminary distribution list of caddisflies for the Rocky Mountain States of Colorado, Idaho, Montana, New Mexico, Utah and Wyoming; a total of 91 species were detailed for New Mexico. In 2009, Vieira et al. documented 43 species of caddisflies from the Valles Caldera National Preserve located in Sandoval Co., New Mexico. Five species were reported as new state records or country records, with two new species collected that were not described previously in published literature.

2.3.4 Oklahoma

Bowles and Mathis (1992) documented a total of 145 caddisfly species from 15 families and 46 genera within Oklahoma. They sampled the eastern mountainous regions of Oklahoma as well as incorporated museum records from the Illinois Natural History Survey, Oklahoma Museum of Natural History, and University of Arkansas Arthropod Museum to produce their species list. As mentioned above, Moulton and Stewart (1996) provided a caddisfly species list for the Interior Highlands. A total of 146 caddisfly species were reported from the eastern Arbuckle and Wichita mountain ranges of Oklahoma. Zuellig et al. (2006) published an annotated list of caddisflies from Fort Sill (Comanche County), Oklahoma. Through this survey a total of 59 species of caddisflies were documented with four species as new state records. A previous survey of Fort Sill by Vaughn and Obermeyer (2002) reported only 34 species of caddisflies.

2.3.5 Texas

Early caddisfly work in Texas was limited in the geographical extent by either representing a country or water body level survey (Hall 1950, Edwards and Arnold 1961, Resh et al. 1978). Subsequent surveys of caddisflies in Texas focused on smaller geographical locations or watersheds: Big Bend State Park and Ranch (Baumgardner and Bowles 2005), Comal Springs (Bowels 1994), Dolan Falls Ranch in Val Verde County (Easley 1996), Brazos River (Moulton et al. 1993), and the Big Thicket (Abbott et al. 1997). The first statewide inventory was compiled by Edwards (1973) and documented 91 species primarily from the Edwards Plateau of south-central Texas. In 1990 Moulton and Stewart (1997) began a long-term survey to inventory the caddisflies of Texas covering the diverse physiographic regions within the state. A variety of sampling methods were employed at ~200 sampling locations from which they documented 199 species from 20 families and 51 genera.

2.4 Natural History Collection's Literature Review

2.4.1 Importance of Natural History Collections

The establishment of natural history museums (NHM) began in Europe in the 16th century to showcase global flora and fauna. The importance of natural history collections (NHC) as a means for research was established in the United States during the 1800s through the founding of several NHM's (Merhoff 1996) Natural history collections provide a wealth of taxonomic and community information as well as useful baseline data for scientific studies across a wide range of disciplines (e.g. GIS, genetics, biogeography, paleontology, conservation, etc. (Lister, 2011)). In recent decades the desire to preserve NHC has come to the forefront of biodiversity projects due to their invaluable records for establishing baseline species data. This is due in part to peer reviewed published data that has become more commonly focused on protecting habitat and documenting threatened species (Boakes et al. 2010).

Natural history museums serve as a “biodiversity library” providing a connection to the past that is lost in large database type repositories like the International Union for the Conservation of Nature (IUCN). These research collections provide information concerning a specimen’s location and date collected, information vital to understanding biogeography on large spatial and temporal scales (Ward 2012). Besides the specific data for a specimen, the inherent value of natural history collection records lies within their historical context, taxonomic and geographical span, as well as the vast number of specimens associated with curators who possess valuable expertise (Boakes et al. 2010, Ball-Damerow et al. 2015). Specimens housed in natural history collections can be used for morphological studies and to resolve taxonomic questions via molecular techniques while their associated data can be used to document species range expansion or decline, community composition, habitat associations, and species phenology (Mehroff 1996; Ward 2012). Furthermore, these records can fill in gaps where sampling is no longer possible due to landscape changes (e.g. reservoir construction, urbanization etc.) and allows for sampling costs to be targeted towards under represented areas.

Currently, the most common questions asked using museum records are ecological and environmental (e.g. criteria for selection areas for conservation, species decline, biogeography and climate change) (Pyke & Ehrlich, 2010). The biggest factors impacting the use of this data are ease of access (e.g. electronic database) and sampling effort (Pyke & Ehrlich, 2010). An example of this time consuming effort to establish baseline data through NHC records was reported by Boakes et al. (2010) who used NHC records along with a variety of other sources to establish baseline data for the Order Galliformes (partridges, pheasants, and quail). They collected, and georeferenced over 171,000 records, an effort that took 1,500 person-days utilizing 18 persons. In 1999, the Global Biodiversity Information Facility (GBIF) was discussed as a solution to facilitate the accessibility of global biodiversity data through a single clearinghouse and was established in 2001(GBIF 2017a). GBIF is not the only enterprise like this, but it is the largest and it is seen as a move towards narrowing the gap between available electronic data and hard to access natural history collection data (Beck et al. 2014). Digitizing NHC records began in the 1970s by 2010 approximately 3% of worldwide records were available electronically (Ball-Damerow et al. 2015).

2.4.2 Biases in Natural History Collections (NHCs)

One of the overarching concerns in NHC records is the bias of species records attributed to charismatic species or by geographical and time scales (Boakes et al. 2010, Yang et al. 2013). Limited information on species geographical distribution affects the ability to document the full extent of species ranges a phenomenon is known as the 'Wallacean shortfall' (Lomolino 2004, Yang et al. 2013). While most bias is focused on geography, there is bias in digitization of invertebrate records, which lag behind those of vertebrates (Schuh et al. 2010). This lag has been attributed to the vast number of invertebrate samples in museums worldwide (Ball-Damerow et al. 2015). Another type of bias is that of local experts, who focus on one or a limited variety of taxonomic groups, therefore inadvertently providing an incomplete regional species inventory and this may lead to misleading spacial patterns of biodiversity (Hortal et al. 2007, Boakes et al. 2010, Ballesteros-Mejia et al. 2013, Yang et al. 2013).

Trichoptera occurrences worldwide total over 1.3 million, but the GBIF database only documents 12,585 (2017b) of the world's caddisfly 14,548 species (TWC 2017). Likewise, caddisfly records restricted to the United States yields 73,991 occurrences with the vast majority, 70% (51,959), reported from the Illinois Natural History Survey (INHS) dataset (GBIF 2017b). The NHC data acquired from the INHS for this study contained the most number of records and the 2nd highest number of reported species. However, if data for this study were only retrieved from the Trichoptera GBIF dataset the number of reported species would be 36% less (Table 4.2.1).

Boakes et al. (2010) suggested that one effort to minimize geographical bias could be done through citizen scientist activities reporting on species. Online biodiversity projects like iNaturalist use an interactive format that allows laypersons as well as experts to post pictures and observations of flora and fauna and associated geographic coordinates with their observations. This format allows for interactions between individuals and fosters verification of records from taxonomic specialists (iNaturalist 2017). In some instances this can prove to be very useful, the more people that are out documenting organisms they encounter the better chance at discovering or rediscovering species. There are also organizations like Texas Parks and Wildlife Department that have citizen scientist programs focused on documenting a variety of organisms within a state's political boundaries. Texas Nature Trackers has a variety of citizen scientist projects including freshwater mussels, amphibians and Monarch butterflies (TPWD 2017a). While programs like iNaturalist and Texas Nature Trackers are valuable for some faunal groups they would be of limited value for organisms such as caddisflies that require more morphological details for species identification than a photograph provides.

CHAPTER 3

METHODS

This chapter provides a description of the study area and locations of samples (Section 3.1); record sources (Section 3.2); 2011-2016 caddisfly sampling (Section 3.3); georeferencing of sample locations (Section 3.4); Geographical Information Systems, scale and resolution, distributional mapping and geographical factor selection (Section 3.5); processing and identification of caddisflies (Section 3.6); taxonomy scheme (Section 3.7) statistical analyses (Section 3.8).

3.1 Study Area and Sample Locations

The study area of the south-central United States included; Arkansas, Louisiana, New Mexico, Oklahoma and Texas; a total of 563,248 mi^2 (1,465,845 km^2) (Figure 3.1). This area of the United States includes the following physiographic provinces: Basin and Range, Central Lowland, Coastal Plain, Colorado Plateau, Great Plains, Ouachita, Ozark Plateaus, and the Southern Rocky Mountains (Figure 3.2)(USGS 2015a). It is divided into 47 HUC 4 sub-watersheds representing the larger watersheds of the Arkansas/White/Red Rivers, lower sections of the Colorado and Mississippi Rivers, Rio Grande, upper Colorado River, and the South Atlantic and Texas Gulf Regions (Figure 3.3)(USGS 2016). Average annual precipitation ranges from 70 inches (178 cm) in the eastern temperate forests to 10 or less inches (25 cm) in the arid western deserts (Figure 3.4).

Figure 3.1: Map south-central United States (1,465,845 km^2).

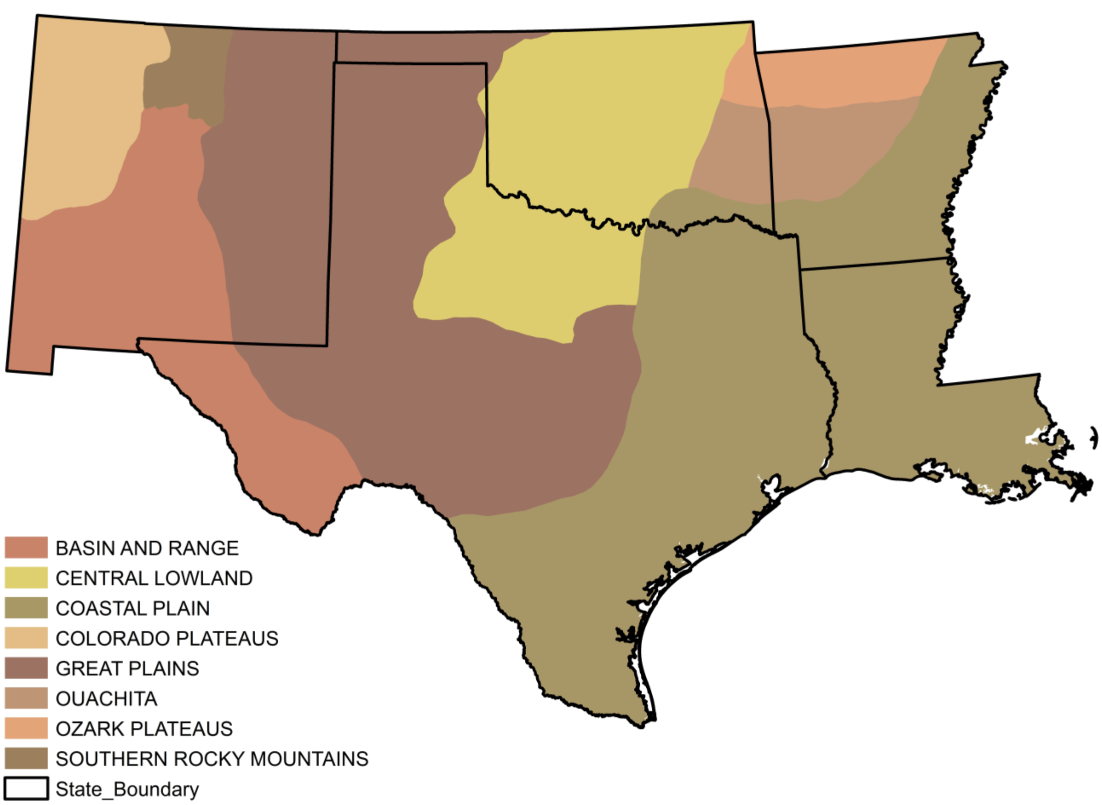


Figure 3.2: USGS physiographic provinces within the south-central United States; 8 provinces are within the study area (2015a).

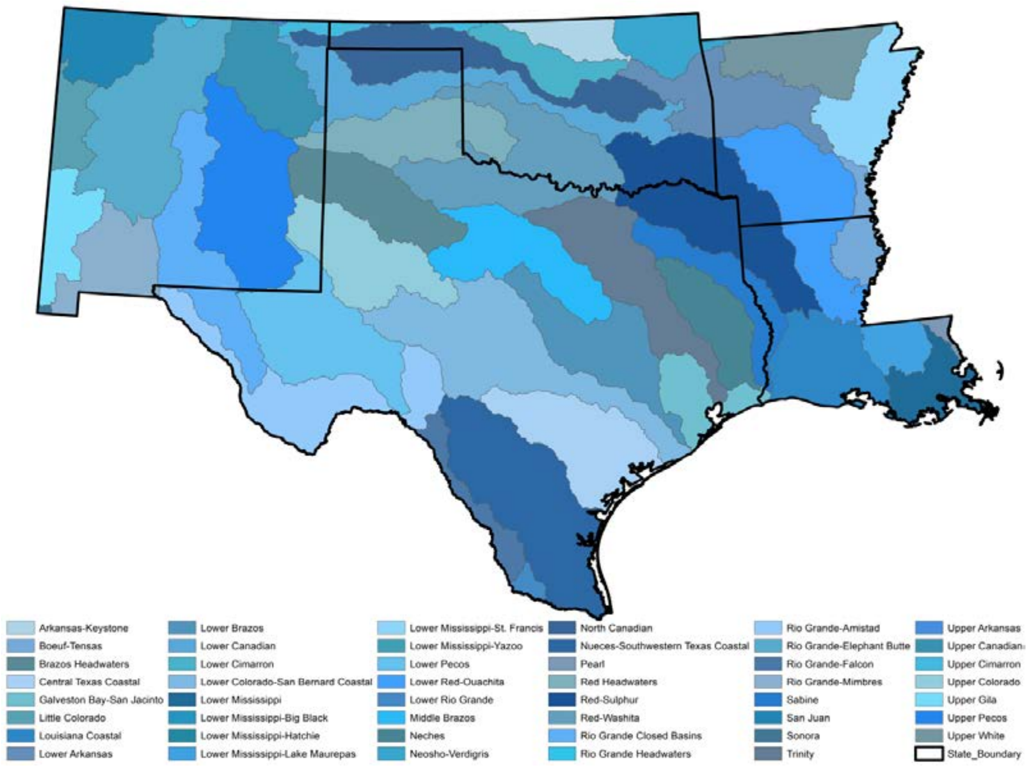


Figure 3.3: HUC 4 Sub-watersheds of the south-central United States: 47 sub-watersheds are within the study area (USGS 2016).

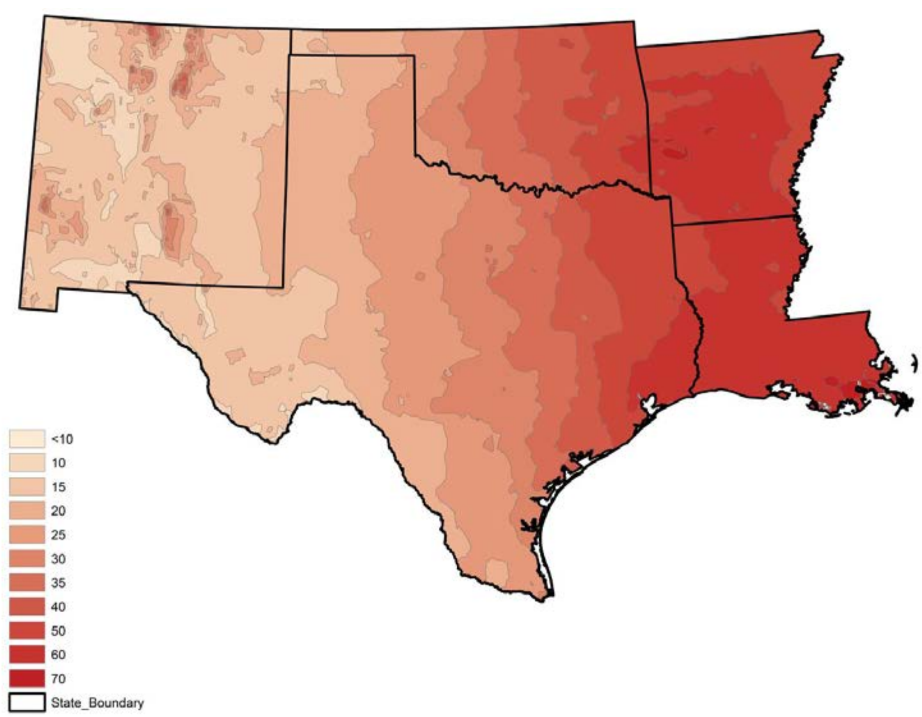


Figure 3.4: Average annual precipitation (inches) within the south-central United States (2005-2009), the map depicts a gradient with higher rainfall in the east with decreasingly less rainfall in the west (National Atlas of the United States 2011).

Sample locations are depicted in Figure 3.5 and are demarked as locations obtained from NHC records and 2011-2016 Heather A. Perry sampling. A total of 1,915 unique sampling locations were documented and are broken down by state: 615 Arkansas; 144 Louisiana; 285 New Mexico; 223 Oklahoma, and 648 Texas. Supplemental sampling targeted under represented areas of southwestern Louisiana, southeastern Texas and eastern New Mexico.

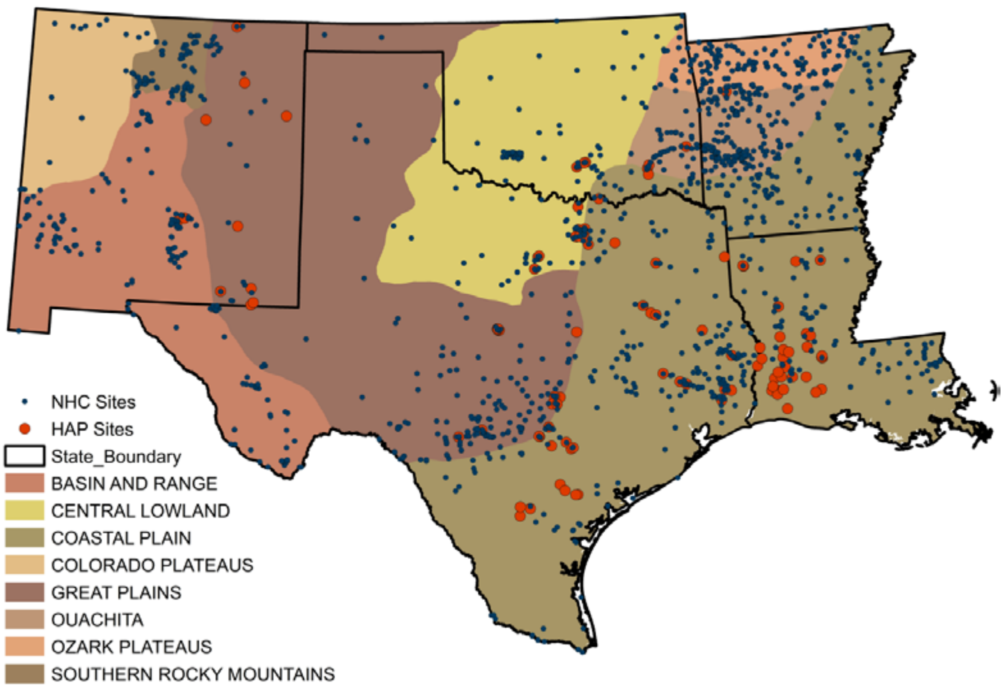


Figure 3.5: Sampling locations by physiographic provinces compiled from Natural History Collections (NHC) and Heather A. Perry sampling 2011-2016 (HAP); a total of 1,915 sampling locations were documented from the south-central United States.

3.2 Natural History Record Sources

The gathering of historical natural history collection (NHC) records was accomplished using the following: 1) determining NHC's to contact consisted of using search engines to produce a list of viable museums and personal collection holders to contact, 2) contacting personnel at museums to ascertain if they possessed caddisfly records for the south-central United States, 3) locating searchable electronic databases for museums or biodiversity repository projects and lastly 4) transcribing NHC records in person when there was no electronic records available. A total of 36 museums or online databases were contacted or searched for records (Table 3.1). Several institutions possessed records that were not accessible electronically. In person transcription of these records was done during the summer of 2013 at Clemson University, Louisiana State Arthropod Museum at the University of Louisiana, Texas Memorial Museum at the University of Texas, Texas A&M University and University of Arkansas.

Furthermore, an unpublished document provided by Rasmussen and Morse *(*(2016) was used as a primary source for peer reviewed publication distribution information on caddisfly species. Regional species lists are known for Arkansas (Bowles and Mathis 1989, Frazier et al. 1991 and Unzicker et al. 1970), Oklahoma (Bowles and Mathis 1992), Texas (Bowles et al. 1993, Bowles 1994, Morse 1993, Easley 1996 and Moulton and Stewart 1997) and Louisiana (Harris et al. 1982, Holzenthal et al*.* 1982 and Lago et al. 1982) and were crossed referenced to ensure that known and potential species for the south-central United States is as complete as possible.

Table 3.1: Thirty-six natural history collections or personal collectors were contacted in order to document Trichoptera records from the south-central United States. This table describes provides a point of contact for each collection and whether or not data was retrieved through a variety of methods. A total of 18 collections provided data for this project.

Museum	Location	Contact	Records
American Museum of Natural History	New York, NY		
Alabama Natural History Museum	Tuscaloosa, AL	Dr. M. Ward	Jun 2013
Arthropod Museum - New Mexico State University	Las Cruces, NM	G. Davis	Jul 2013
Arthropod Museum - University of Arkansas	Fayetteville, AR	Dr. J. Barnes	Aug 2013
C.P. Gillette Museum of Arthropods-Colorado State University	Fort Collins, CO		

(table continues)

Museum	Location	Contact	Records
California Academy of Science	San Francisco, CA		
City of Austin Watershed Protection Department	Austin, TX	R. Clayton	Aug 2012
Colorado Plateau Musseum of Arthropod Biodiverstiy	Flagstaff, AZ		
Cornell University Insect Collection	Ithaca, NY		
David E. Ruiter	Oregon		Mar 2014
Elm Fork Natural History Museum	Denton, TX		Oct 2011
Frank F. Hasbrouck Insect Collection	Tempe, AZ		
G.P. Setliff Collection	Kutztown, PA		
Global Biodiversity Information Facility			Feb 2017
Illinois Natural History Survey	Champaign, IL	C. Grinter	Feb 2017
Louisiana State Arthropod Museum	Baton Rouge, LA	V. Moseley	July 2013
M.T. James Entomological Collection	Pullman, WA		
Museum of Comparative Zoology-Harvard University	Cambridge, MA		
Museum of Southwest Biology, Division of Arthropods	Albuquerque, NM		July 2013
National Parks Collection			
Natural History Museum of Utah	Salt Lake City, UT		
Oklahoma Biological Survey	Norman, OK		Mar 2014
Oregon State Arthropod Collection	Corvallis, OR		
Smithsonian National Museum of Natural History	Washington D.C.	D. Furth	Oct 2012
Stephen R. Moulton II Collection	Denton, TX		Oct 2011
Texas A&M University Insect Collection	College Station, TX	E. Riley	Jul 2013
Texas Memorial Museum	Austin, TX	Dr. J. Abbott	Oct 2012
The Clemson University Arthropod Collection	Clemson, SC	Dr. J. Morse	Jul 2013
The Invertebrate Zoology-Texas Tech University	Lubbock, TX		
Tulane University Biodiversity Research Institute	Belle Chase, LA		
University of Alaska Museum Insect Collection	Fairbanks, AK		
University of Arizona Insect Collection	Tucson, AZ		
University of Colorado Museum of Natural History Entomology Collection	Boulder, CO		
University of Minnesota Insect Collection	Saint Paul, MN	Dr. R. Holzenthal	Mar 2013
Utah Dept of Agriculture and Food Entomology Collection	Salt Lake City, UT		
Yale Peabody Musem of Natural History	New Haven, CT		

3.3 2011-2016 Caddisfly Collection and Preservation

Adult caddisflies were collected using Optronics Blackeye Beam® (Muskogee, OK) dual-tube ultraviolet 8–watt black light and white fluorescent light placed face down over a white enamel pan (39 cm X 25 cm X 5 cm) filled with 80% ethanol (Figure 3.6). Lights were placed next to aquatic habitat approximately 1-2 hours prior to sunset and retrieved 2-3 hours after sunset.

Figure 3.6: Black light trap and battery configuration used for the collection of adult Trichoptera at Anacoco Bayou, Louisiana.

Collections of adults were also made at various locations with a 175-watt mercury vapor light (MVL) placed in front of a white sheet (Figure 3.7). MVL collections began 1 hour prior to sunset. Adult caddisflies attracted to the light were handpicked form the sheet for 2-3 hours or until no new families of caddisflies were collected specimens. Unidirectional 2-meter Townes style malaise insect traps (Sante Traps, Lexington, Kentucky) were used over streams to collect caddisfly adults. This trap was set on occasions where the trap could be left up for several days for long term collecting. Adults in this trap were preserved in 80% ethanol.

Figure 3.7: Mercury vapor light (MVL) trap setup (left) and the use of an aspirator (right) in collecting adult caddisflies during MVL trapping at Palmetto State Park, San Marcos River, Texas.

Additional records were identified from various student collections that were complied as part of course requirements for Insect Biology and Aquatic Insects of North America taught at the University of North Texas (Denton, TX) and are housed as part of the Elm Fork Natural Heritage collection. Samples collected from 2011-2016 are annotated throughout as HAP (Heather A. Perry) sites Table 3.2 provides a list of those sample locations and dates.

Table 3.2: Heather A. Perry (HAP) sampling locations for south-central United States, a total of 65 locations were sampled from 2011-2016.

ST	Date	County/Parish	Lat/Long		Water Body	Method
TX	13-V-11	Gonzales	N 29.468472	W -97.491833	Guadalupe R.	BLT
TX	13-V-11	Gonzales	N 29.589927	W -97.585054	San Marcos R.	BLT
TX	14-V-11	Gonzales	N 29.489584	W -97.450164	Guadalupe R.	MVL
TX	17-V-11	Comal	N 29.7061	W -98.12191	Guadalupe R.	BLT
TX	17-V-11	Hayes	N 29.869518	W -97.930304	San Marcos R.	MVL
TX	01-III-12	Denton	N 33.33635	W -97.030909	Trinity R.	BLT
TX	02-III-12	McLennon	N 31.525955	W -97.290764	Hog Ck.	NA
TX	24-VI-13	Karnes	N 28.848594	W -97.737125	San Antonio R.	BLT
TX	25-VI-13	Golidad	N 28.655566	W -97.390183	San Antonio R.	BLT
TX	21-IX-13	Denton	N 33.263922	W -97.052572	Clear Ck.	NA
TX	12-III-14	Denton	N 33.058445	W -96.971306	Trinity R.	NA
TX	19-III-15	Denton	N 33.195073	W -97.070285	Pecan Ck.	NA
TX	28-IV-14	Denton	N 33.241956	W -97.151237	Northlakes Pond	NA
TX	08-VI-14	Guadalupe	N 29.5347	W -97.88498	Guadalupe R.	BLT
TX	19-VI-14	Live Oak	N 24.43353	W -98.35008	Nueces R.	BLT
TX	19-VI-14	McMullen	N 28.30787	W -98.55674	Nueces R.	BLT
TX	19-VI-14	McMullen	N 28.46789	W -98.54738	Frio R.	BLT
TX	20-VI-14	Golidad	N 28.65144	W -97.43286	San Antonio R.	BLT
TX	20-VI-14	Golidad	N 28.73597	W -97.64283	San Antonio R.	BLT
TX	07-VII-14	Travis	N 30.391944	W -97.675833	Walnut Creek	BLT
TX	09-VII-14	Travis	N 30.405826	W -97.793553	Bull Ck.	BLT
TX	16-VII-14	Travis	N 30.273951	W -97.844506	Barton Ck.	BLT

(table continues)

ST	Date	County/Parish	Lat/Long		Water Body	Method
TX	01-X-14	Denton	N 33.200327	W -97.215555	Hickory Ck.	MVL
TX	24-X-14	Harrison	N 32.702937	W -94.123489	Caddo Lake	BLT
TX	23-VII-15	Denton	N 33.202712	W -97.231591	Hickory Ck.	NA
TX	11-VI-16	Denton	N 33.203608	W -97.154521	Pond	MAL
NM	3-V-15	Eddy	N 32.31209	W -104.06024	Pecos R.	BLT
NM	3-V-15	Eddy	N 32.02207	W -104.05358	Delaware R.	BLT
NM	3-V-15	Eddy	N 32.06444	W -104.00642	Pecos R.	BLT
NM	4-V-15	Chaves	N 33.39693	W -104.38733	Pecos R.	BLT
NM	5-V-15	Lincoln	N 33.44834	W -105.66239	Rio Bonnito	BLT
NM	5-V-15	Lincoln	N 33.50012	W -105.52251	Rio Bonnito	BLT
NM	6-V-15	Quay	N 35.35437	W -103.41532	Canadian R.	BLT
NM	6-V-15	Mora/Harding	N 35.91409	W -104.34819	Canadian R.	BLT
NM	7-V-15	San Miguel	N 35.23912	W -105.16069	Pecos R.	BLT
NM	9-V-15	Colfax	N 36.8865	W -104.56335	Canadian R.	BLT
LA	11-III-14	Calcasieu	N 30.217699	W -93.248519	Lake Charles	BLT
LA	12-III-14	Beaureguard	N 30.86438	W -93.07296	Ouisak Chitto Ck.	BLT
LA	12-III-14 16-III-15	Vernon	N 30.94625	W -92.94871	Six Mile Ck.	BLT
LA	14-III-14	Calcasieu	N 30.36351	W -93.327247	W Fork Calcasieu R.	MVL
LA	16-III-14	Vernon	N 30.99488	W -93.05296	Ouiska Chitto Ck,	BLT
LA	16-III-15	Vernon	N 31.22579	W -93.10107	Calcasieu R.	BLT
LA	16-III-15	Vernon	N 31.06419	W -93.52803	Sabine R.	MVL
LA	17-III-15	Rapides	N 31.20086	W -92.51049	Middle Bayou	BLT
LA	17-III-15	Rapides	N 31.24288	W -92.55166	Bayou Boeuf	BLT

(table continues)

ST	Date	County/Parish	Lat/Long		Water Body	Method
LA	17-III-15	Rapides	N 31.19984	W -92.47444	Bayou Boeuf	BLT
LA	17-III-15	Rapides	N 31.0085	W -92.56171	Spring Ck.	BLT
LA	17-III-15	Evangeline	N 30.79077	W -92.26987	Chicot Lake	BLT
LA	17-III-15	Evangeline	N 30.80754	W -92.28407	Chicot Lake	BLT
LA	17-III-15	Evangeline	N 30.82869	W -92.27451	Chicot Lake	MVL
LA	19-III-15	Acadia Parish	N 30.19829	W -92.46374	Bayou Placquemine Brule	BLT
LA	19-III-15	Jefferson Davis/Acadia	N 30.48079	W -92.63327	Bayou Nezpique	BLT
LA	19-III-15	Allen Parish	N 30.5024	W -92.91405	Calcasieu R.	BLT
LA	19-III-15	Beaureguard	N 30.6845	W -93.04426	Bundick Ck.	BLT
LA	20-III-15	Calcasieu	N 30.2915	W -93.35535	Calcasieu R.	BLT
LA	20-III-15	Beaureguard	N 30.50107	W -93.28053	Cole, Horse & Wild Cow Creeks	BLT
LA	20-III-15	Beaureguard	N 30.5174	W -93.14156	Barnes & Brush Creek Confluence	BLT
LA	20-III-15	Beaureguard	N 30.60752	W -93.19572	Barnes Ck.	BLT
LA	20-III-15	Beaureguard/Newton	N 30.74665	W -93.60755	Sabine R.	BLT
LA	20-III-15	Vernon/Beaureguard	N 30.86733	W -93.50964	Anacoco Bayou	MVL
LA	19-III-15	Calcasieu	N 30.29628	W -93.11839	Calcasieu R.	BLT
OK	12-IV-12	Murray	N 34.495893	W -96.988209	Rock Ck.	MVL
OK	12-IV-12	Murray	N 34.502179	W -96.854952	Unnamed Spring	MVL
OK	12-IV-12	Murray	N 34.493978	W -96.989049	Rock Ck.	MVL
OK	10-IV-14	Pushmataha	N 34.339864	W -95.634809	Kiamichi R.	MVL

Methods: BLT – black light trap; MVL – mercury vapor light; MAL – malaise trap; NA – not available.

3.4 Georefrencing Natural History Collection Records

Records obtained from NHC were georeferenced using Google Earth (2012) when no geographic coordinates were provided. Most records contained location descriptions of county, cross roads, water body, or some combinations of these. In the event when a location could not be determined due to limited collection information one of the following was used: 1) if a description from the nearest town was given that town's latitude and longitude coordinates were used or 2) if a description was of a location that contained no real landmarks other than the county, the county seat was used for latitude and longitude coordinates. Records without usable collection location information were not included in the analyses.

3.5 Geographical Information Systems and Selection of Geographical Variables

ArcGIS 10 (ESRI 2012) was used to produce maps of sampling locations and species distributions as well as an attribute table consisting of geographic variables used for statistical analyses. Selection of factors for this project was based upon variables that are known to impact life cycles of larval and adult caddisflies (e.g. ecoregions, physiographic regions, precipitation and hydrologic units) as well as the appropriate scale (e.g. local, regional)(Galbraith et al. 2008).

Variables selected for this study contained multiple scales (e.g. local, regional). In order to determine which geographical scale was the most appropriate for delineating trichopteran community assemblage's preliminary analyses were run in PRIMER-E (version 6). The results of non-metric multi-dimensional scaling diagrams (NMDS) as well as the Analysis of Similarity outputs (ANOSIM) were used to establish which scales of selected variables were most appropriate for this study (see section 3.8). The variables used for this study are: Level II ecoregions, physiographic provinces, hydrologic unit code 4, and average annual precipitation.

Data for selected variables was obtained from the following sources: Level II ecoregions (EPA 2012), physiographic provinces (USGS 2015a), and Hydrologic Unit Code 4 (USGS 2015b). Precipitation data is based upon average annual precipitation data (2005-2009) complied by National Atlas of the United States (2011), and is for use specifically at national or large regional areas.

3.6 Processing and Identification of Caddisflies

Samples were sorted under an Olympus® SZ51 stereomicroscope in the laboratory to family and then into subsequent lower taxonomic levels. Male caddisfly genitalia were cleared using the KOH/Acetic Acid/Ethanol method (Betten 1934, Mosely 1943, Ross 1944) for clearing insect abdominal tissue. This same method was used to clear whole Hydroptilidae specimens due to their small size. Species identification was based on adult male caddisfly genitalia morphological characteristics as well as the associated published species description. Species identification of Hydroptilidae were done using an Olympus® BH-2 compound light microscope. Appendix A provides a detailed list of the taxonomic resources used for species identification. The following experts provided species identification or verification:

- Dr. S. C. Harris with the Department of Biology at Clarion University, Clarion, PA. Identified or verified specimens/species from the following families: Hydroptilidae and Glossosomatidae.
- Dr. O.S. Flint, Jr. Curator Emeritus, Neuropteroids, Department of Entomology, National Museum of Natural History Smithsonian Institute

verified or identified specimens/species from the following families: Apataniidae, Brachycentridae, Dipseudopsidae, Hydrobiosidae, Phyrganeidae, Polycentropodidae, Hydropsychidae and Calamoceratidae.

- D.E. Ruiter, Trichoptera specialist, verified or identified specimens/species from the following families: Helicopsyche, Hydropsychidae, Leptoceridae, Philopotamidae and Polycentropodidae.

3.7 Classification Scheme

Records gathered for this project span over a century and therefore required updating to current taxonomic nomenclature. I followed the phylogeny put forth by Kjer et al. (2001, 2002) and Holzenthal et al. (2007) for the trichopteran suborders, infra-orders and families. Species names were verified through peer reviewed literature, Trichoptera World checklist (TWC) and Rasmussen and Morse 2016. Appendix B provides a list of the species reported for the study area.

3.8 Statistical Analyses

3.8.1 Uneven Sampling

Caddisfly records were treated as having uneven sampling efforts regardless of abundance data due to the inability to document sampling methods and effort. For records with no abundance counts it was assumed that at least 1 specimen was collected. The inability to document sampling method and effort for records from locations that reported low number of species led to the inability to address the following questions: 1) it cannot be discerned if said record was from incidental findings from collections that were focused on another organism(s), 2) if they represent actual sampling designed to document Trichoptera species or 3) from the material processed only a single species could be determined due to damage or only males of said species were collected. Therefore, all samples were treated equally even if sampling method and effort were known.

3.8.2 Data Purged

Records were purged from analyses if they contained identifications only to the Order or Family level, or if the location was limited to the state. NHC records identified to species were removed if the reported taxonomy 1) was invalid based on published distributions (e.g. outside of Nearctic distributions), or 2) the taxonomic name was invalid and had not been synonymized with an existing species. Verification of caddisfly species taxonomy and distribution was done using Rasmussen and Morse (2016) and the Trichoptera World Checklist (2017).

3.8.3 Best-fit Trichoptera Biogeographic Regions and Community Structures

Trichopteran "best-fit" biogeographic region delineation was done through ANOSIM and NMDS analyses using the statistical software PRIMER-E version 6 (Clarke and Warwick 2001). ANOSIM analyses were used to determine geographic factors that influence caddisfly community structure and determine the minimum number of species (e.g. 8, 10 etc.) required to maximize geographic differences. The ANOSIM procedure is analogous to a 1-way ANOVA and uses standardized rank correlation between resemblance matrices to determine the amount of variation between samples that have been grouped by some factor or experimental treatment. PRIMER-E outputs a Global R statistic for ANOSIM that reflects the standardized rank correlation among samples and is generated with a statistical significance value (*p* value) determined through a randomized permutation procedure. Samples are permuted among factor groupings and the Global R statistic is calculated for each new data configuration. This process develops a null distribution for the Global R statistic that is centered around zero (average rank resemblance among and within factor groups is similar and R will be near zero) for comparison to the real data. Acceptance or rejection of the null hypothesis (no difference between groups) is achieved through comparison of the true value of the Global R statistic to the null distribution; a true R near the null distribution suggests the data distribution could have been obtained by chance while a large difference signifies structure to the data and high confidence in rejecting the null. The actual *p* value is related to the number of permutations selected *a priori* and can be made arbitrarily large or small based on the number of permutations run. Since this analysis is based on a series of permutations to determine the validity of the null hypotheses, a table of pairwise tests is provided; this allows the user to determine what environmental factors could be influencing the tested hypothesis if the null hypothesis is rejected (Clarke and Gorley 2006).

NMDS analyses output were used to spatially assess geographical factors and community structure visually. Samples (points) are arranged (plotted) in a specified number of dimensions that attempts to satisfy all the conditions imposed by the rank (dis) similarity matrix of the NMDS analysis. Plots can be scaled, located, rotated or inverted because samples are placed arbitrarily within the plots. The relationship between points (how they are arranged in space) is based upon how similar or dis-similar they are to each other. Arrangement of points on 2-D plots is the “best fit” and this arrangement can also be viewed in PRIMER-E’s *n*-dimensional plot allowing the user to understand the relationship between factor groupings that may be skewed, or not as easily visible with 2-D plots (Clarke and Warwick 2001).

The full data set was reduced for the PRIMER-E analyses by first removing caddisfly records containing only identifications above the species level and then removing sites that reported only a single caddisfly species. Sites reporting only a single species were removed under the assumption that 1) the sample was only an incidental collection or 2) sampling effort was diminished for some reason (i.e. weather, time of year, poor habitat etc.). Data reduction left a total of 1,723 sites for use in the PRIMER-E analyses.

The average number of species for the HAP collection (8) was used as a starting baseline for running the PRIMER-E analyses and estimating the minimum number of species needed to determine the relation between caddisfly community structure and geographic variables. Sites were tallied for species richness and all sites with a species count under the first target number (8) were dropped from the analysis. A series of ANOSIM and NMDS analyses were then conducted while increasing the species count required to be included in the analysis. Minimum species counts assessed in the analyses ranged from 8 to 15.

3.8.4 Caddisfly Community Similarity

After determination of the “best-fit” geographic factor based on the minimum number of caddisfly species was selected through ANIOSIM and NMDS analyses a species similarity percentage analysis (SIMPER) was used to determine the role of individual species in contributing to the separation between two groups of samples or the relatedness of samples within a group (Clarke and Gorley 2006). Average Bray-Curtis values are “decomposed” into percent contributions by each species, and are ranked from highest to lowest values (Clarke and Gorley 2006). The user has the option in this analysis to impose a restriction cut-off; this is done to avoid long species lists where many have small or no contributions to the dissimilarity between sites or groups (Clarke and Gorley 2006).

CHAPTER 4

RESULTS

This chapter provides associated data and statistical results for natural history collection historical records and HAP 2011-2016 sampling. Section 4.1 provides historic accounts from natural history collections; Section 4.2 additional records from literature; Section 4.3 Heather A. Perry sampling (2011-2016); Section 4.4 caddisfly demographics; Section 4.5 new species records; Section 4.6 endemic species; Section 4.7 species of concern; Section 4.8 Neotropical species distributions; and Section 4.9 biogeographic region structure and statistical analyses.

4.1 Historical Accounts from Natural History Collections

A total of 36 NHC were contacted to determine if they had records documenting caddisflies from the south-central United States (see Table 3.1). Of those 18 NHC's (Table 4.1) contained records that were used for this project with a total of 12,426 records, of those 10,297 are associated with species identifications (Table 4.2). Each record is a unique combination of caddisfly species, collection date, and collection location. Records were subsequently placed within sampling locations based upon unique sampling coordinates and could contain multiple collection dates.

Table 4.1: Contributing Natural History Collection (NHC) Institutions data sources and their corresponding abbreviations for the south-central United States Trichoptera.

Location of NHC Records Obtained	Abbreviation
Alabama Natural History Museum	ANHM
Clemson University	CLM
City of Austin Watershed Protection Dept	COA
Colorado State University	CSU

(table continues)

Location of NHC Records Obtained	Abbreviation
David E. Ruiter Collection	DER
Elm Fork Natural History Museum	EFNHM
Illinois Natural History Survey	INHS
Louisiana State Arthropod Museum	LSAM
Museum of Southwestern Biology	MSWB
New Mexico State University	NMSU
Smithsonian Natural History Museum	SNHM
Stephen R. Moulton II, Collection	SRM Coll
Texas A&M University	TXAM
Texas Memorial Museum	TXMM
University of Arkansas	UAR
University of Minnesota, Saint Paul	UMSP
Unknown source of data	UNKNOWN
Global Biodiversity Information Facility	GBIF

Table 4.2: Total number of Trichoptera records gathered from NHC for the south-central United States.

Records	Total
Total NHC Records	12,426
Total NHC Species Records	10,297
Total NHC Genus Records	1,872
Total # Species Records w/o year collected	257

From these historic NHC records at total of 411 species are reported from 1900-2016 (Figure 4.1), this is 29% of the ~1,400 species reported for North America (Wiggins and Currie 2008) but represents only 3% (14,548) of the world's known species of caddisflies (TWC 2017). A total of 23 families were documented from the study. They represent 88% of the North American families, and 47% of global caddisfly families. Of the 150 caddisfly genera known from North America, 92 are represented in this study and comprise 15% of the extant Trichoptera genera (Wiggins and Currie

2008, TWC 2017). Fifty-nine percent of the caddisfly species reported via NHC records are from three families: Hydropsychidae, Hydroptilidae, and Leptoceridae (Figure 4.1). The most specioes family is Hydroptilidae, which are represented in 30% of reported historic records. *Hydroptila* is the most specioes genera totaling 41 species or 10% of the documented species from the south-central United States. *Hydroptila* spp., constitute 34% of the reported NHC Hydroptilidae species.

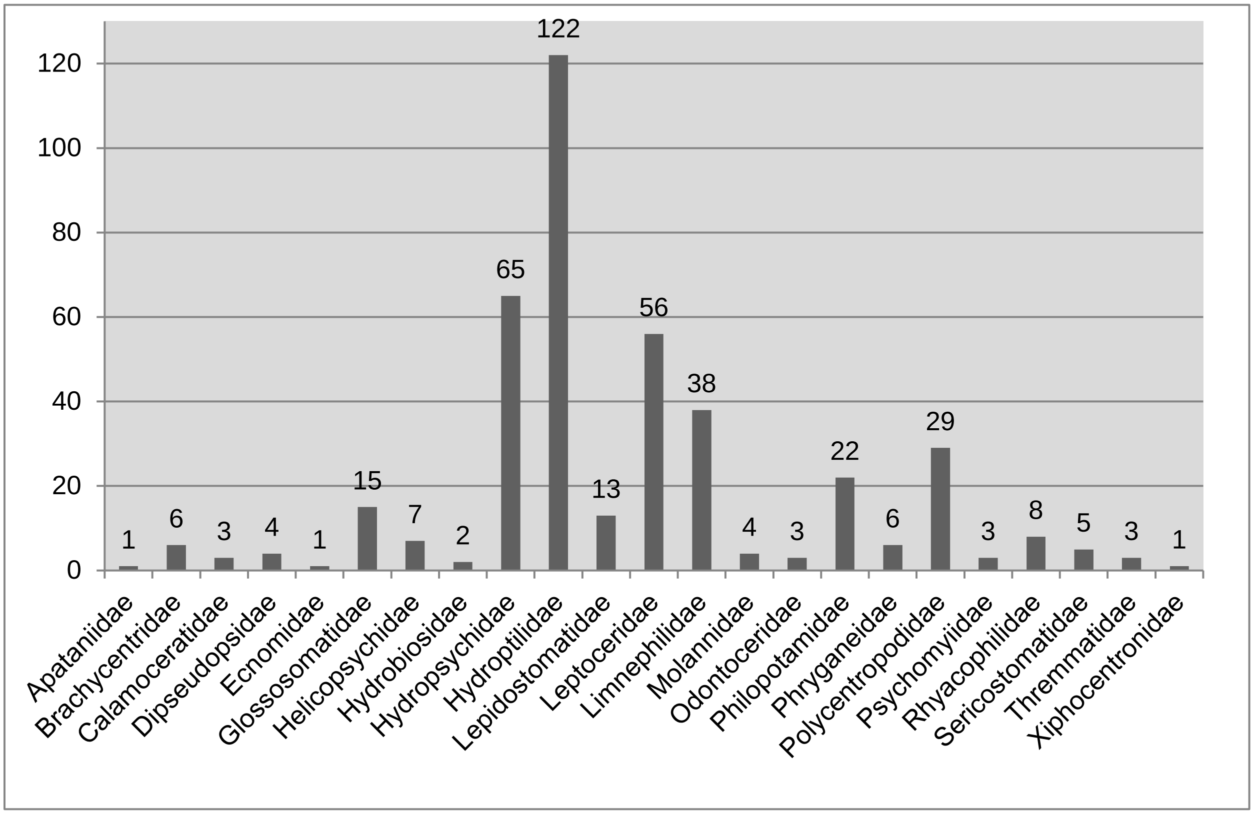


Figure 4.1:Total number of species by family documented from NHC records (1900-2016); a total of 24 families representing 87 genera were documented for the south-central United States. Hydroptilidae “micro caddisflies” was the most specioes families containing 122 documented species.

Since 1900 the majority of NHC caddisfly records within the study region were collected over a 13-year period (1985-1998) (Figure 4.2). Prior to 1958 (temporal mid-point) the 3-year period (1937-1939) had the most caddisfly record gathering. Post 1958 shows a steady increase in species reported each year with the period from 1985-1998 being the most productive period of record gathering and species documented (Figure 4.2). The year, 1993, contains the most number of records (1,020) and species reported 174 (Figure 4.2), which corresponds to intensive sampling in Texas by S.R. Moulton and colleagues. During 2002-2004 a total of 1,277 records were collected, with the vast majority during 2003. While reporting more records than the 1970s, sampling during the 2000s reported a similar number of species (166 vs.162).

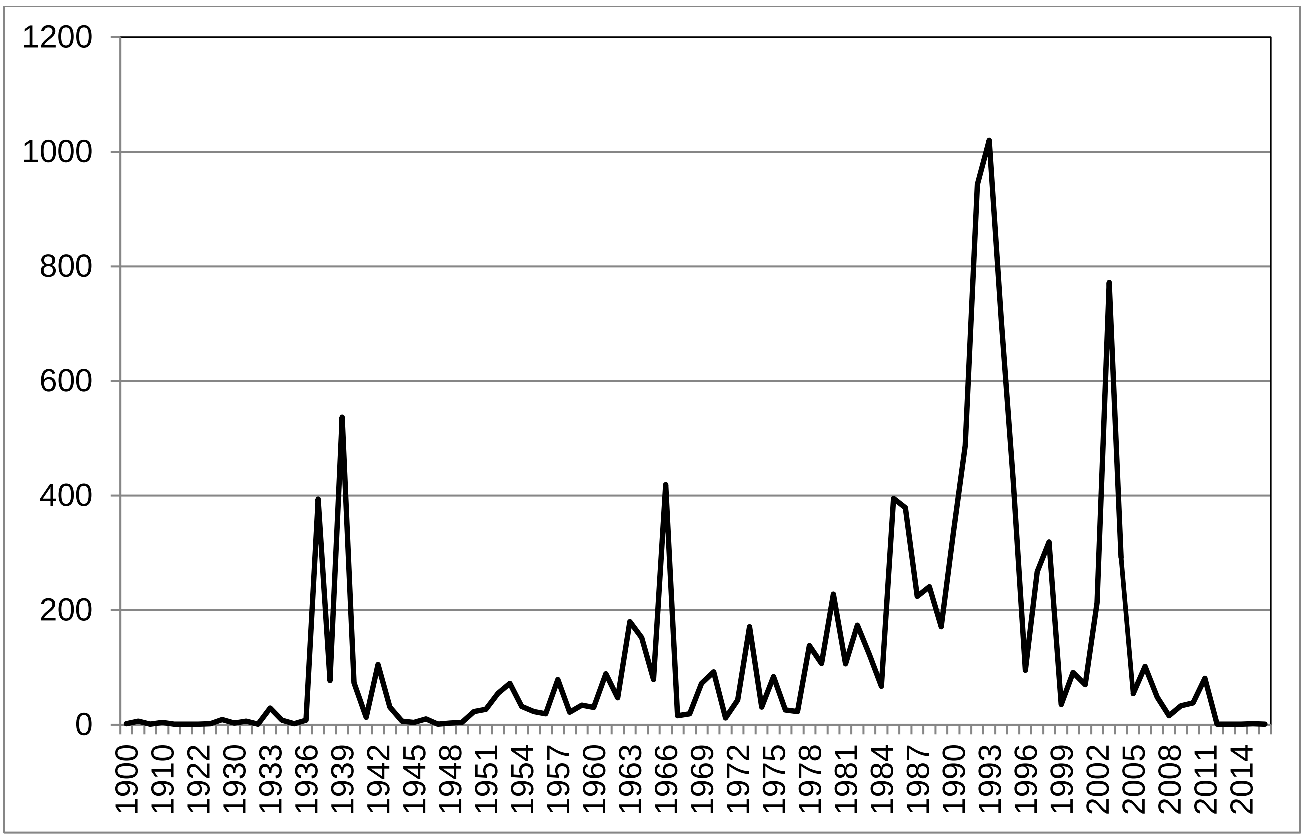
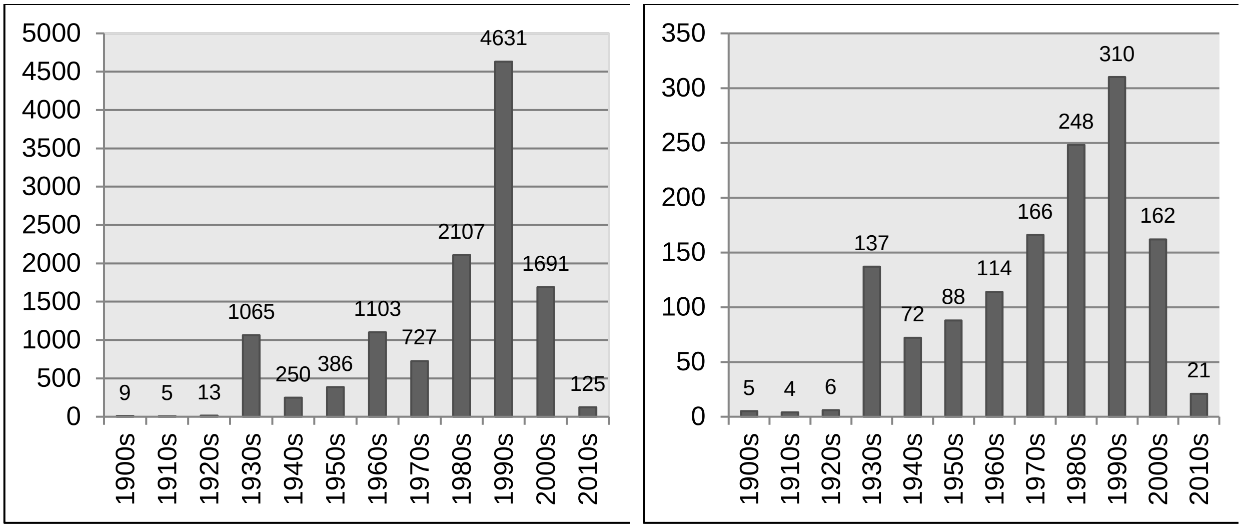


Figure 4.2: Total number of Trichoptera records per year 1900-2016.

The number of records and species reported by decade from NHC's is shown in Figure 4.3. NHC records increase in the 1980s through the 2000s, but the majority are reported from the 1990s. Subsequent species documentation does not near the 1930s species count until the 1970s when 166 species were documented for the decade.



RECORDS SPECIES

Figure 4.3: Bar graphs depicting the total number of records and species by decade gathered from NHC historical records from 1900-2016.

Figures 4.4 and 4.5 provide a breakdown of the number of records and species obtained by NHC institution. Two NHC collections Stephen R. Moulton (SRM Coll) and David E. Ruiter (DER) contained records gathered from other owner institutions such as Brigham Young University and Purdue University, for example, as well records collected by them personally. Records they gathered from other owner institutions were not recorded as separate NHC's but left as part of their collection records.

Records obtained from the 18 NHC were dominated by three collections, Steven R Moulton (SRM Coll), Illinois Natural History Survey (INHS) and David E. Ruiter (DER). The INHS and SRM Coll provided the bulk of usable records of all the NHC (6,625, 53%). The majority of the records from the INHS are from Arkansas (48%, 1,621), while the bulk of the SRM Coll records are from Texas (75%, 2,456). SRM Coll documented 288 (70%) of the 411 species reported from NHC records. These three NHC's provided most (8,918 or 72%) of the historic records obtained to document the baseline of caddisflies species known from the south-central United States. Together they documented a total of 393 or 96% of the species reported from the study area. However, records from these NHC over represent Texas and Arkansas (Table 4.3) by 38.7% and 30.5%, respectively.

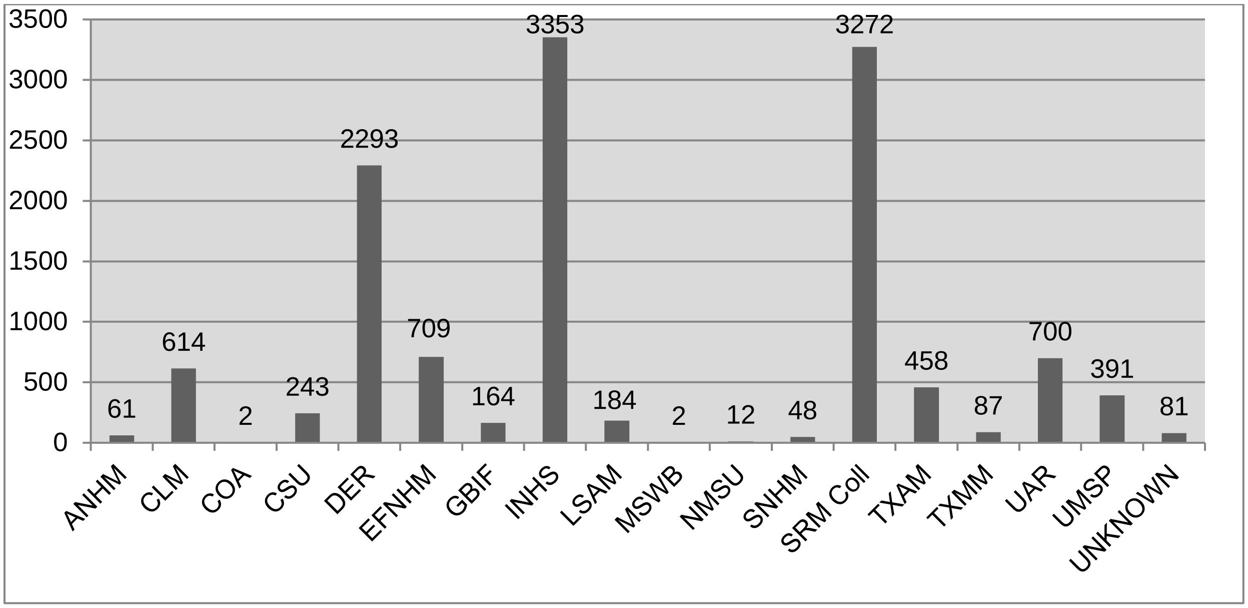


Figure 4.4: Total number of NHC records by owner institution. A total of 12,426 records were gathered from 18 NHC.

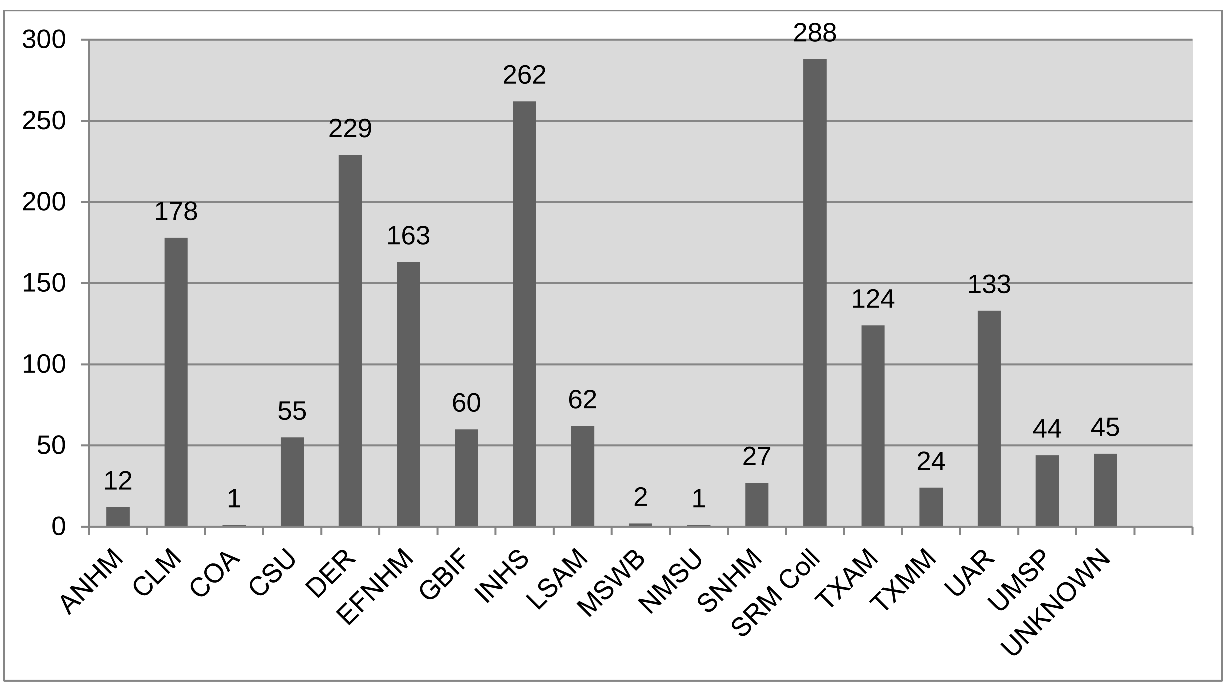


Figure 4.5: Total number of species reported by each NHC institution. A total of 411 species were recorded from 18 NHC institutions.

Table 4.3: Records for top 3 NHC broken down by state. Total number of records for these 3 NHC is 8,919 or 72% of the total number of NHC records.

State	INHS	DER	SRM Coll	Total	Percent
Arkansas	1,620	544	560	2,724	30.5
Louisiana	101	3		104	1.2
New Mexico	390	564		954	10.7
Oklahoma	573	849	256	1,680	18.8
Texas	669	325	2,465	3,459	38.7

4.1.1 Arkansas Trichoptera

A total of 4,238 records from 614 unique sampling locations (Table 4.4) were reported for Arkansas. Records were gathered from 16 NHC and represent 34% of all historic records. The INHS provided the bulk of these records (38%)(Table 4.4), and 77% (3,256) records contained species level identification. Sampling locations are from 65 (87%) of the 75 Arkansas counties (MOW 2017) (Figure 4.6). One hundred ninety-seven species were documented for Arkansas, representing 17 families and 53 genera. Four species are endemic to the state (Appendix B). They represent 44% of the known species from the study region. The families documented from Arkansas (Figure 4.7), three families represent 58% of the species records: Hydropsychidae, Hydroptilidae, and Leptoceridae.

Table 4.4: Number of records from 15 NHC institutions and number of reported unique sampling locations reported for Arkansas.

NHC Institution	# of Records	NHC Institution	# of Records
ANHM	61	SNHM	22
CLM	333	SRM	560
DER	544	TXAM	16
EFNHM	161	TXMM	16
GBIF	11	UAR	668
INHS	1,620	USMP	141
LSAM	1	UNKNOWN	81
NMSU	3	Total Locations	614
Total Records	4,238	Species Only	3,256

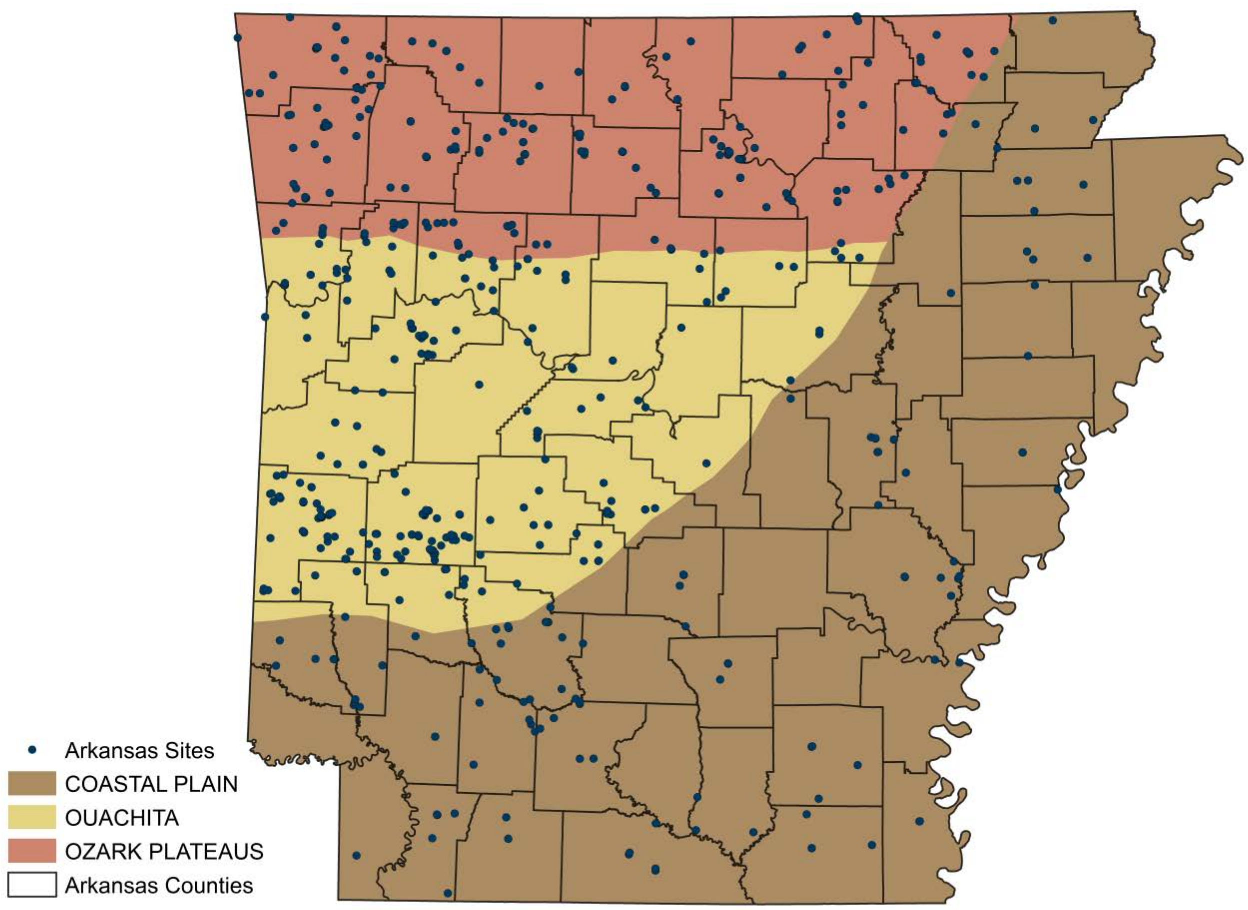


Figure 4.6: Arkansas sampling locations by physiographic province, 65 of Arkansas's 75 counties were sampled for this study with a combined total of 615 unique sampling locations (NHC 614, HAP 1).

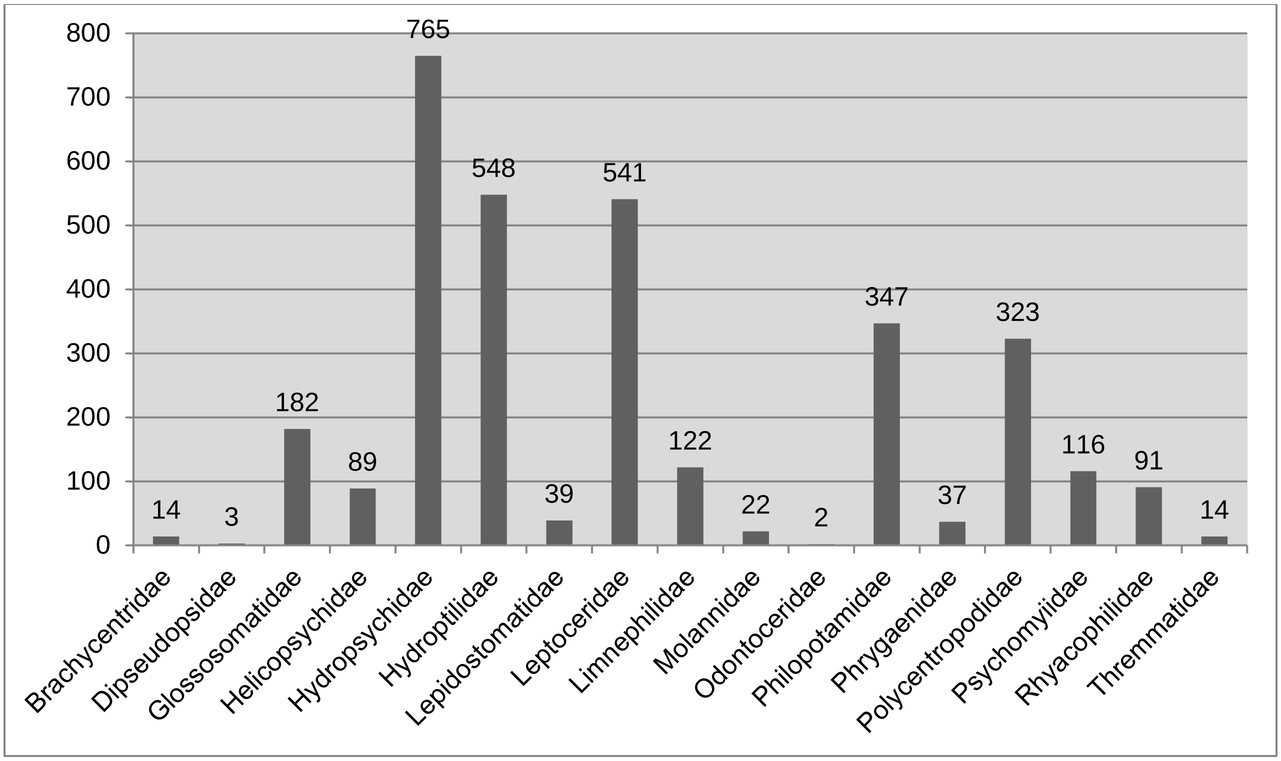


Figure 4.7: Arkansas Trichoptera families reported from NHC records from 1900-2016. Bar graph illustrates the number of records recorded by family that were identified to species. The most collected families were Hydropsychidae, Hydroptilidae and Leptoceridae and represent 57% of the species identified records. Hydropsychidae was the most collected family with 765 records.

The most specioes families are Hydropsychidae, Hydroptilidae, and Leptoceridae, which represent 66% or 130 of the species documented from Arkansas (Figure 4.8). Five species represent the most collected species, by number of records, in Arkansas they are: *Chimarra feria* (Philopotamidae) (110), *Polycentropus centralis* (Polycentropodidae) (115), *Potamyia flava* (Hydropsychidae) (116), *Chimarra obscura* (Philopotamidae) (126) and *Ochrotrichia anisca* (Hydroptilidae) (138). They represent 605 records or 19% of the species records from Arkansas. .

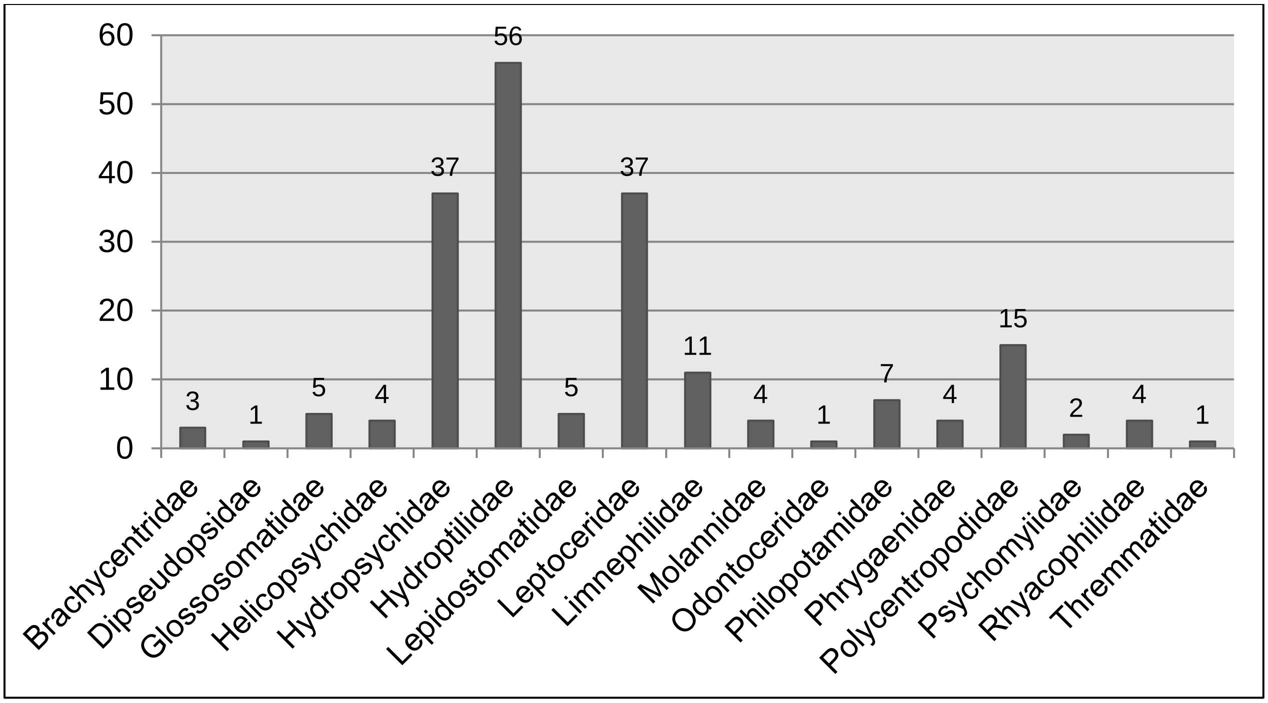


Figure 4.8: Number of species reported by family for Arkansas Trichoptera NHC records from 1900-2016. The most specioes families were Hydropsychidae, Hydroptilidae and Leptoceridae.

4.1.2 Louisiana Trichoptera

A total of 686 records from 11 NHC institutions provided historic caddisfly records for Louisiana. Ninety two percent, 634, of Louisiana's records were identified to species and UMSP records accounted for 29% of the state records (Table 4.5). One hundred five unique locations were sampled from 34 of Louisiana's 64 parishes (Figure 4.9), or 53% spatial coverage (MOW 2017).

Table 4.5: Number of records from 11 NHC institutions and number of reported unique sampling locations reported for Louisiana.

NHC Institution	# Records	NHC Institution	# Records
CLM	165	SNHM	6
DER	3	TXAM	5
EFNHM	17	TXMM	2

(table continues)

NHC Institution	# Records	NHC Institution	# Records
GBIF	5	UAR	2
INHS	101	UMSP	202
LSAM	178	Total Locations	105
Total Records	686	Species Only	52

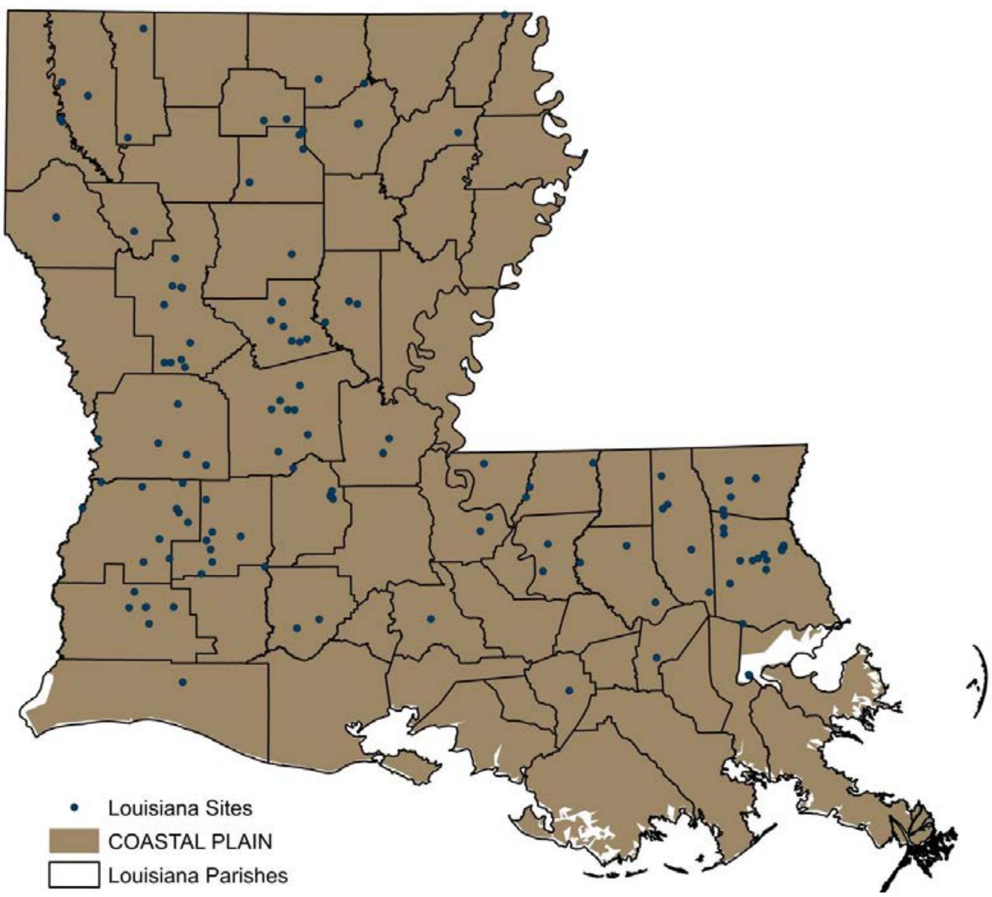


Figure 4.9: A total of 144 sampling locations from Louisiana were documented from 39 parishes, 105 locations from NHC and 39 from HAP sites. Sites were all located in one physiographic province, the Coastal Plain.

One hundred nine species, 37 genera, and 15 families were reported from historic caddisfly records. One species, *Diplectrona rossi* (Hydropsychidae), is endemic to the state. The majority (64%) of records identified to species were from two families: Hydropsychidae and Leptoceridae (Figure 4.10).

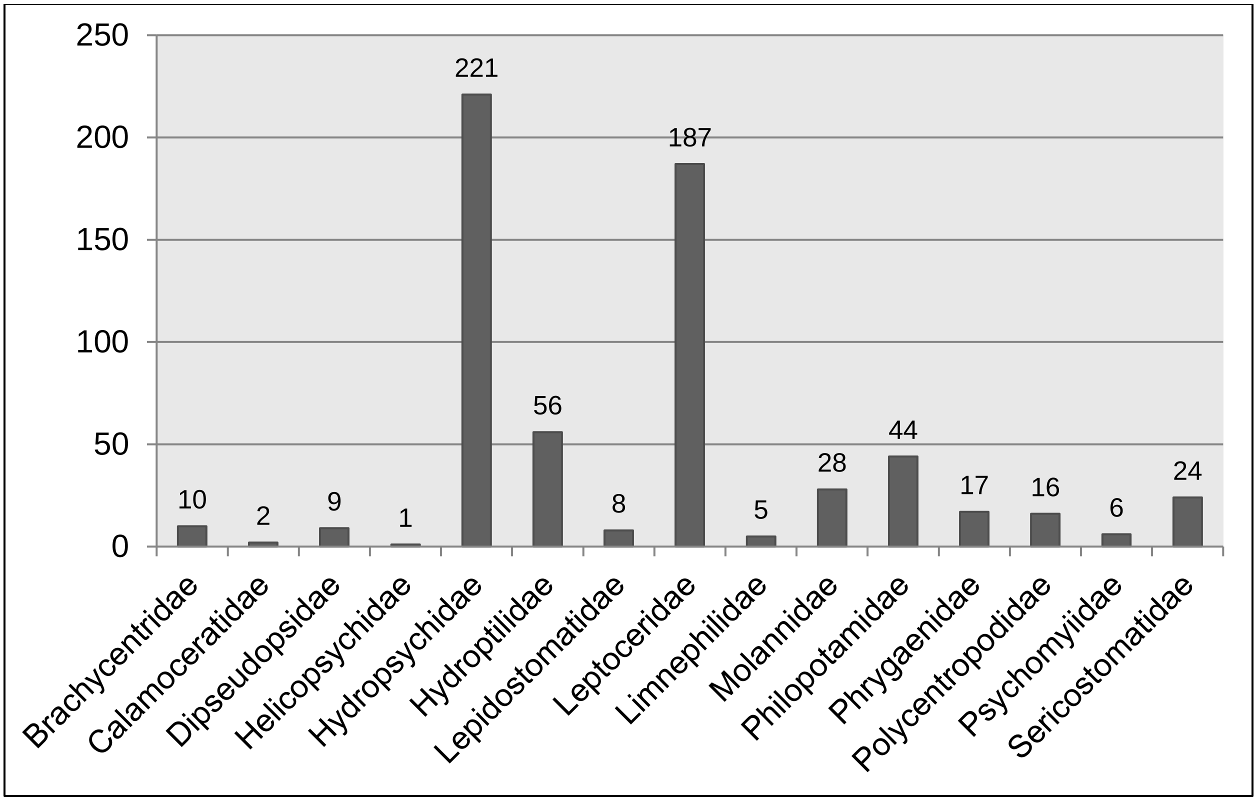


Figure 4.10: Louisiana Trichoptera families reported from NHC records from 1900-2016. Bar graph illustrates the number of records recorded by family that were identified to species. The most collected families were Hydropsychidae and Leptoceridae and represent 64% of the species identified records. Hydropsychidae was the most collected family with 221 records.

The most specioes families for Louisiana are Hydropsychidae, Hydroptilidae and Leptoceridae (Figure 4.11). However, the genera with the most species were *Hydropsyche* (Hydropsychidae) and *Hydroptila* (Hydroptilidae) both represented by 11 species totaling 20% of documented species from Louisiana. The following species of Leptoceridae: *Ceraclea maculata, Oecetis inconspicua, O. sphyra* and *Nectopsyche candida* and Hydropsychidae: *Hydropsyche rossi* and *Cheumatopsyche pinaca* were reported the most often in historic NHC records for Louisiana and account for 30% (193) of the total records for the state. The highest reported species was, *Cheumatopsyche* *pinaca,* for a total of 54 records or 8.5% of the species records. The aforementioned remaining species range from 3.7-5.5% of the species records.

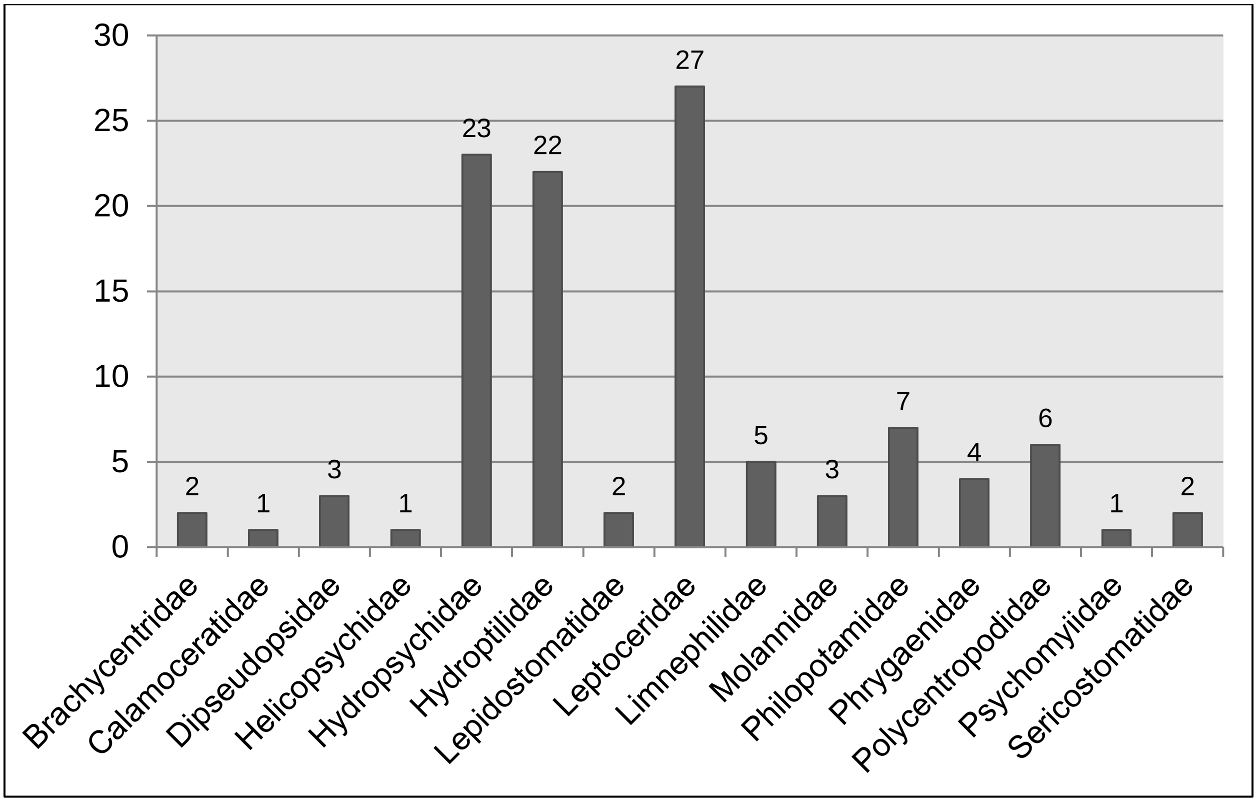


Figure 4.11: Number of species reported by family for Louisiana Trichoptera NHC records from 1900-2016. The most specioes families are Hydropsychidae, Hydroptilidae and Leptoceridae.

4.1.3 New Mexico Trichoptera

Thirteen NHC's provided 1,151 historic records for New Mexico and 82% contained species level identifications. The bulk of New Mexico records were provided by DER and INHS. These institutions account for 952 (83%) of New Mexico's historic records (Table 4.6). Two hundred seventy-four sampling locations were collected from 24 of New Mexico's 33 counties accounting for 73% of the state being covered (Table 4.6, Figure 4.12) (MOW 2017).

Table 4.6: Number of records from 13 NHC institutions and number of reported unique sampling locations reported for New Mexico.

NHC Institution	# Records	NHC Institution	# Records
CLM	8	MSWB	2
CSU	26	NMSU	9
DER	562	SNHM	2
EFNHM	85	TXAM	6
GBIF	44	UAR	11
INHS	390	UMSP	3
LSAM	3	Total Locations	274
Total Records	1,151	Species Only	938

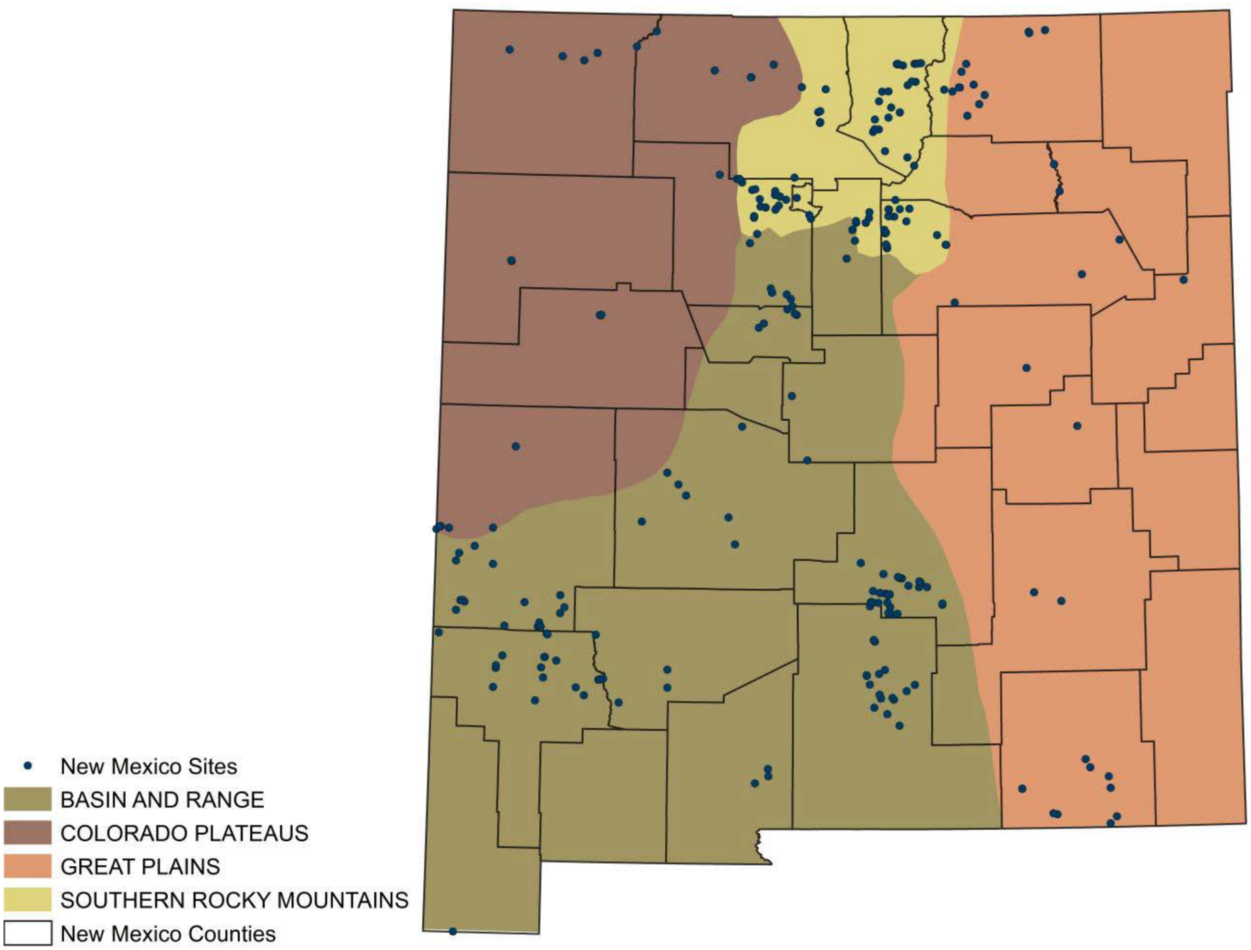


Figure 4.12: New Mexico sampling locations by physiographic province: total 285 (NHC=274, HAP=11); from 26 of 33 counties.

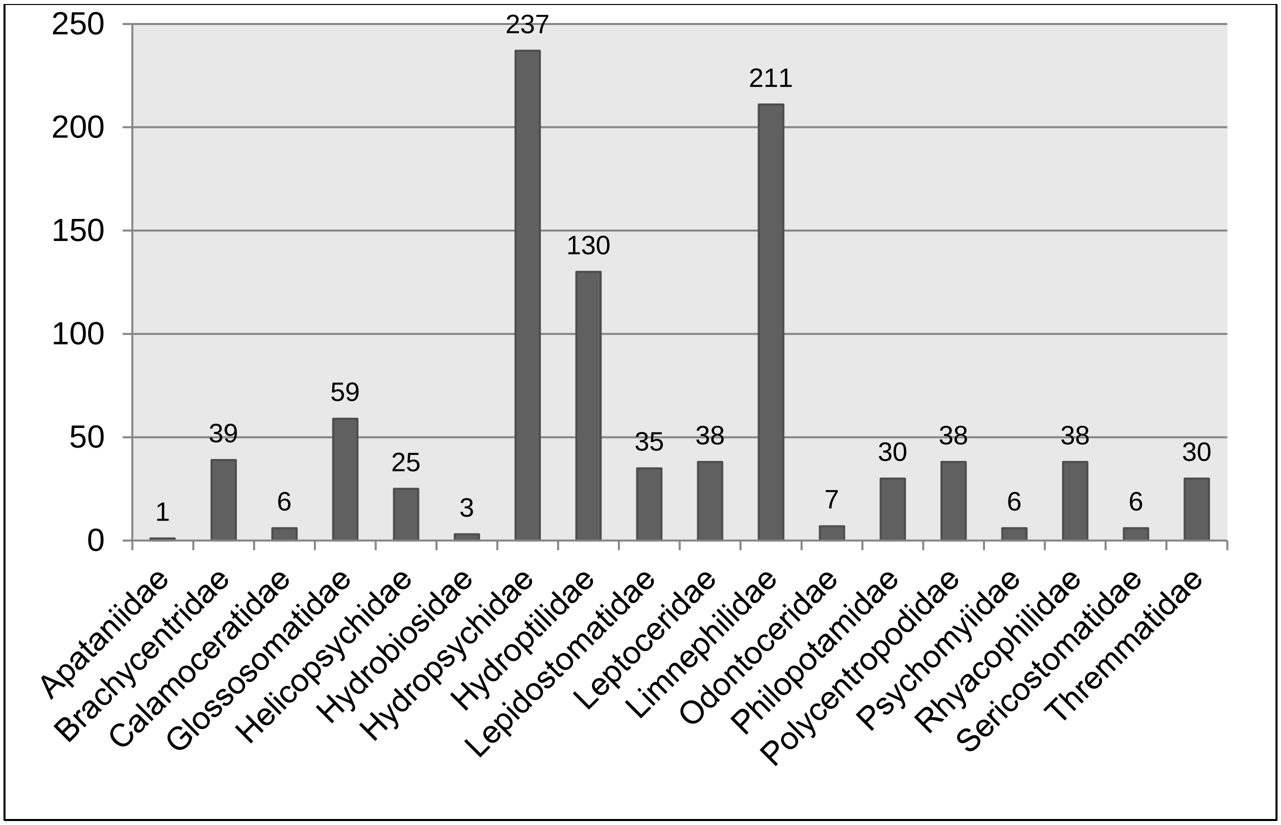


Figure 4.13: New Mexico Trichoptera families reported from NHC records from 1900-2016. Bar graph illustrates the number of records recorded by family that were identified to species. The most collected families were Hydropsychidae and Limnephilidae and represent 48% of the species identified records. Hydropsychidae was the most collected family with 237 records.

Seventeen families, 52 genera and 119 species were reported from New Mexico, with 6 that are endemic (Appendix B). Two families, Hydropsychidae and Limnephilidae, represent 48% of the records reported for New Mexico (Figure 4.13), while the most specioes families were Hydroptilidae and Limnephilidae representing 42% of the states species (Figure 4.14).

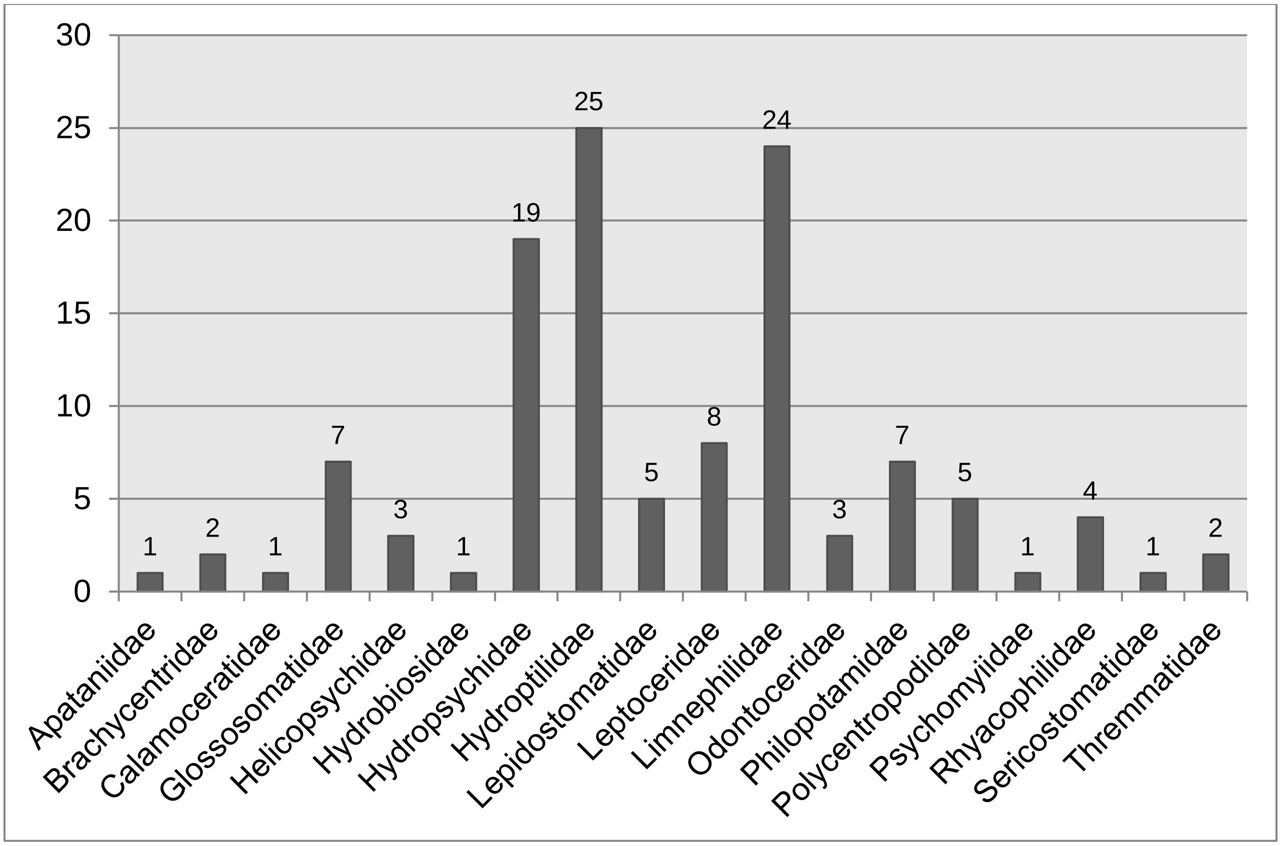


Figure 4.14: Number of species reported by family for New Mexico Trichoptera NHC records from 1900-2016. The most specioes families are Hydroptilidae and Limnephilidae.

The five most collected species by total number of records are: *Oligophlebodes minutus* (Thremmatidae)(29), *Brachycentrus americanus* (Brachycentridae)(32), *Hydropsyche oslari* (Hydropsychidae)(40), *H. occidentalis* (Hydropsychidae)(52), and *Hesperophylax occidentalis* (Limnephilidae)(57). Collectively they represent 22% of the species records from New Mexico. Even though Hydroptilidae is the most specioes family (Figure 4.14), none of the genera in this family were in the top 5 collected genera. The genus that was reported the most often was *Hydroptila pecos* from 20 NHC records. Other Hydroptilidae reported from 10 or more records are: *H. arctia, Ochrotrichia argentea, O. dactylophora and Oxyethira dualis.* The family Apatanidae was unique to New Mexico and reported in only one record where 10 larvae were identified to *Apatania* sp. by David E. Ruiter. This family is associated with cool running waters and is known from both the Holarctic and Oriental faunal regions (Wiggins 1996). *Apatiania* sp. is a montane species typically occurring in spring fed streams (Wiggins 1996).

4.1.4 Oklahoma Trichoptera

Ten NHC provided 2,112 historic records for Oklahoma, with 92% identified to species. The top two contributing institutions are INHS and DER providing 67% of the historic Oklahoman records, with DER accounting for the majority at 40% (Table 4.7). Two hundred fifteen locations were sampled from 40 of Oklahoma's 77 counties covering over 50% of the state (Figure 4.15) (MOW 2017).

Table 4.7: Number of records from 10 NHC institutions and number of reported unique sampling locations reported for Oklahoma.

NHC Institution	# Records	NHC Institution	# Records
CLM	42	SRM	256
CSU	225	TXAM	101
DER	850	TXMM	2
GBIF	54	UAR	6
INHS	573	UMSP	1
Total Records			2,112
Species Only			1,944
Total Locations			215

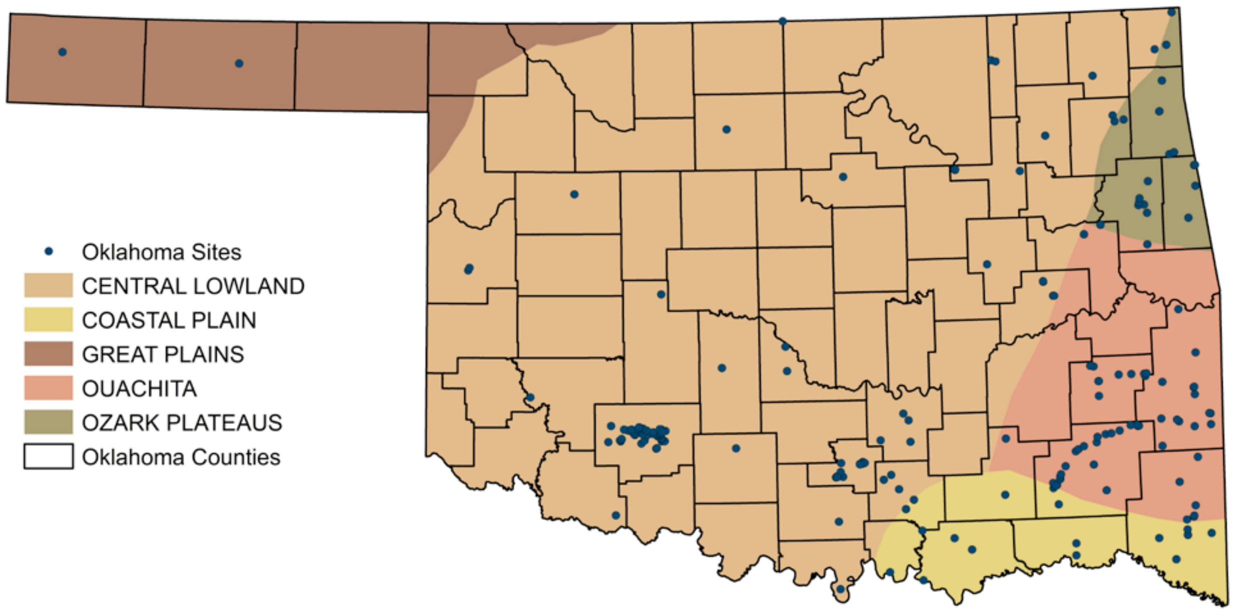


Figure 4.15: Oklahoma sampling locations represented in each physiographic province: total 223 (NHC=215, HAP=8); 41 of the 77 counties from Oklahoma were sampled.

One hundred forty-four species from 16 families and 54 genera were documented from NHC records (Table 4.7, Figure 4.16). Figure 4.16 illustrates the number of records collected by family; the most collected families were Hydropsychidae (32%) and Leptoceridae (28%). The five most commonly collected species by total number of records for Oklahoma are *Cheumatopsyche analis* (Hydropsychidae)(72), *Chimarra obscura* (Philopotamidae)(83), *C. lasia* (Hydropsychidae)(84), *Oecetis inconspicua* (Leptoceridae)(118) and *C. campyla* (Hydropsychidae)(139) and they represent 26% of the species records. However, an additional six species were reported from 50 or more records, and represent species from Hydropsychidae and Leptoceridae mainly (one exception is *Helicopsyche borealis* (Helicopsychidae)). These 11 species represent 44%, or 855 of the 1,944 species records and 8% of the documented species from Oklahoma.

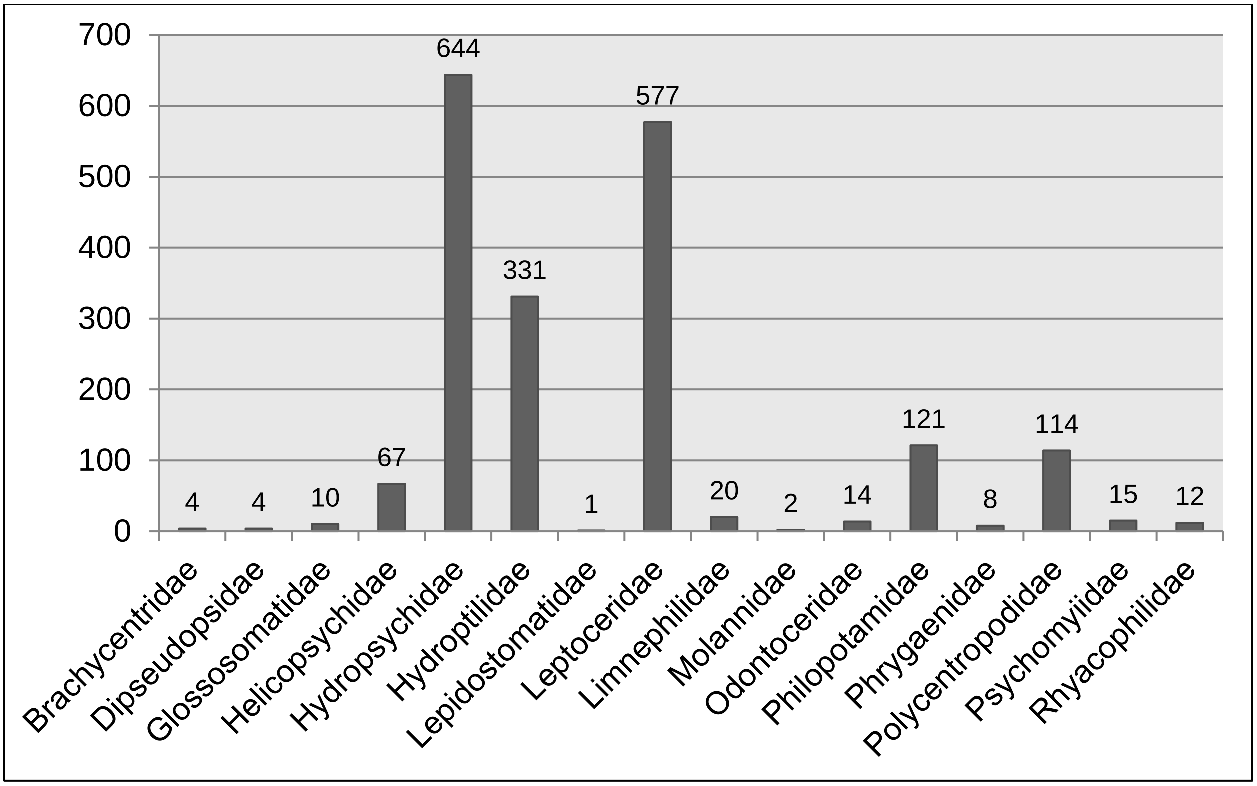


Figure 4.16: Oklahoma Trichoptera families reported from NHC records from 1900-2016. Bar graph illustrates the number of records recorded by family that were identified to species. The most collected families were Hydropsychidae and Leptoceridae and represent 63% of the species identified records. Hydropsychidae was the most collected family with 644 records.

Hydroptilidae and Leptoceridae are the most specioes families from Oklahoma (Figure 4.17). While Hydroptilidae is represented by the most species this family only accounts for 17% of the NHC records from Oklahoma (Figures 4.16 and 4.17). *Hydroptila* was the most collected Hydroptilidae genera, with *H. melia* being the most reported with 38 records. No unique family, genus or species were represented in NHC records for Oklahoma.

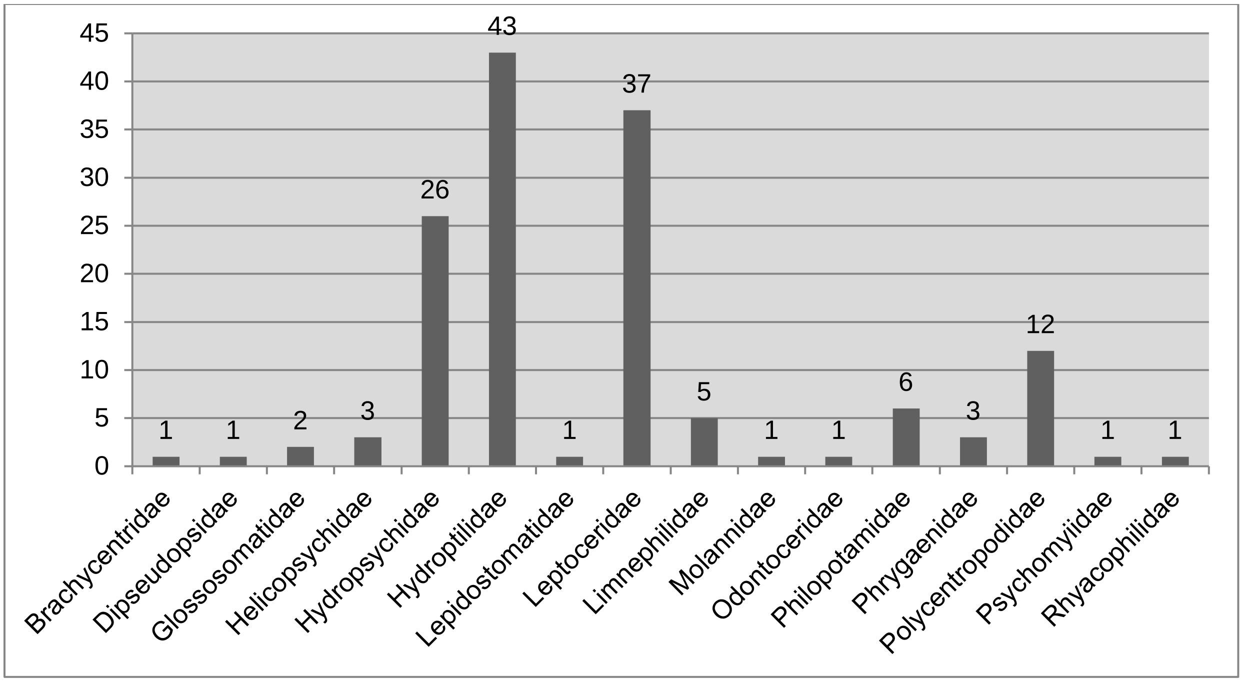


Figure 4.17: Number of species reported by family for Oklahoma Trichoptera NHC records from 1900-2016. The most specioes families are Hydroptilidae and Leptoceridae.

4.1.5 Texas Trichoptera

Fourteen NHC provided 4,240 historic records for Texas with 3,784 (90%) identified to species, the majority (58%) of these records were provided by the SRM Coll (Table 4.8). NHC records for Texas were from 592 unique locations across 118 of Texas's 254 counties (MOW 2017) providing 46% spatial coverage (Figure 4.18).

Table 4.8: Number of records from 14 NHC institutions and number of reported unique sampling locations reported for Texas.

NHC Institution	# Records	NHC Institution	# Records
CLM	66	LSAM	2
COA	2	SNHM	18
CSU	1	SRM Coll	2,465
DER	325	TXAM	330

(table continues)

NHC Institution	# Records	NHC Institution	# Records
EFNHM	188	TXMM	67
GBIF	50	UAR	13
INHS	669	UMSP	44
Total Records			**4,240**
Species Only			**3,784**
Total Locations			**592**

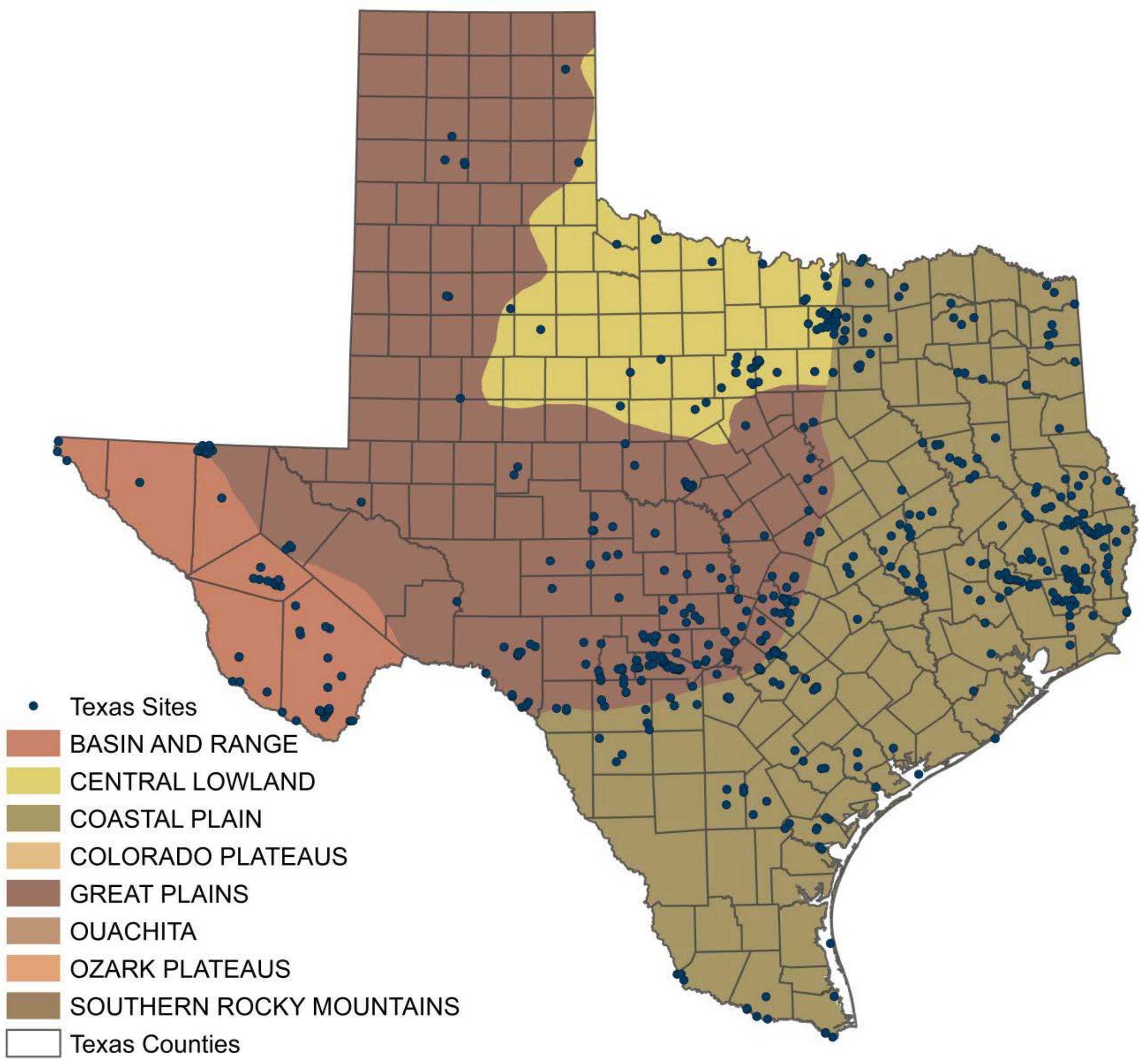


Figure 4.18: Texas sampling locations by physiographic province. A total of 648 unique sampling locations were gathered with 592 from NHC records and 56 from HAP sites.

The number of records identified to species were dominated by the families: Hydroptilidae, Hydropsychidae, and Leptoceridae, totaling 66% of the records from Texas. However, if you account for all families that have over 100 documented records the addition of Philopotamidae and Polycentropodidae account for 3,293 total records identified to species, or 87% of the species records from Texas (Figure 4.19).

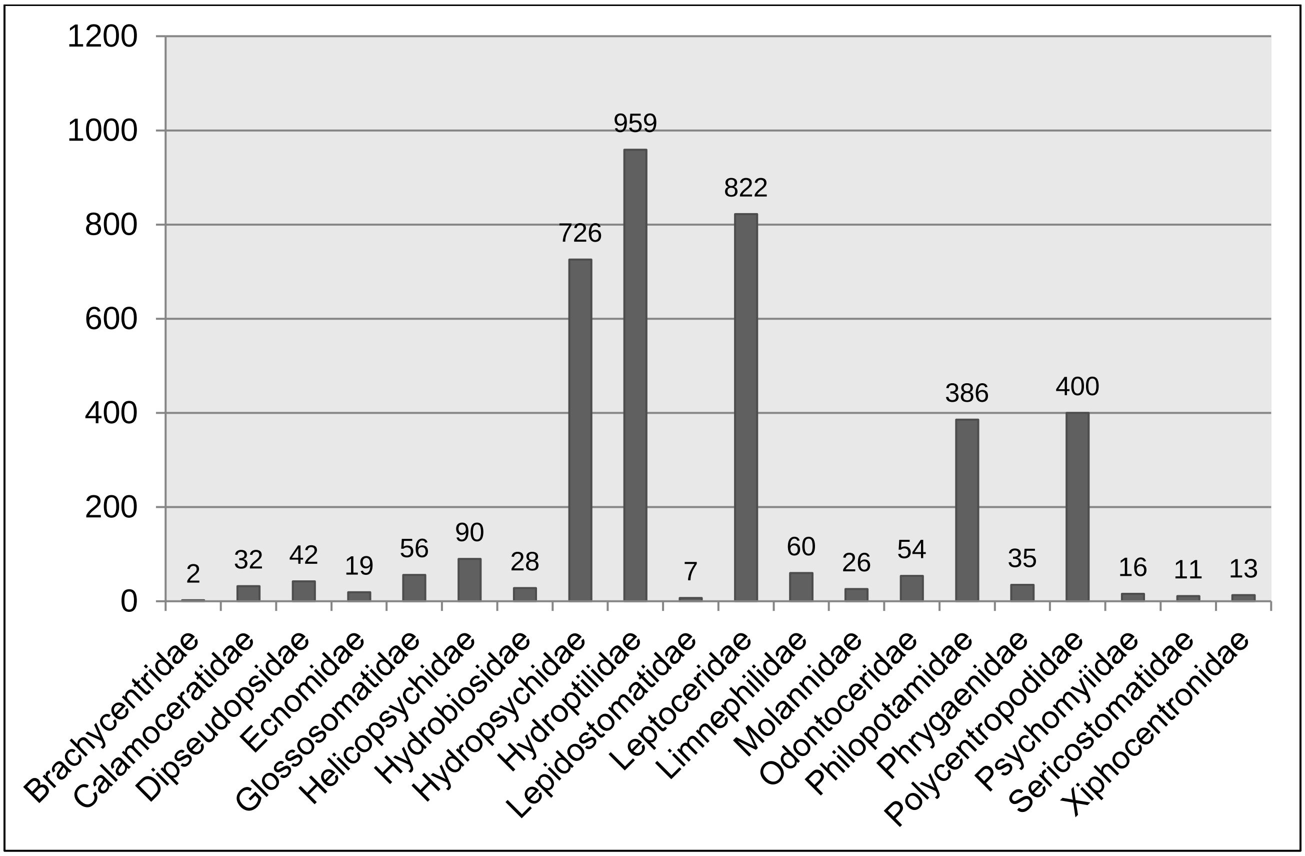


Figure 4.19: Texas Trichoptera families reported from NHC records from 1900-2016. Bar graph illustrates the number of records recorded by family that were identified to species. The most collected families were Hydropsychidae, Hydroptilidae and Leptoceridae and represent 66% of the species identified records. Hydroptilidae was the most collected family with 959 records.

Twenty families of caddisflies were reported from Texas (Figure 4.19) with 2 unique to collections in Texas: Ecnomidae and Xiphocentronidae. Both of these families were represented by a single species *Austrotinodes texensis* (Ecnomidae) and

Xiphocentron messapus (Xiphocentronidae). These families are primarily Neotropical in distribution (e.g. Mexico, Central and South America) (Wiggins 1996) and the two species were documented from the physiographic sections Central Texas and the Edwards Plateau. These 20 caddisfly families represent a total of 52 genera and 215 caddisfly species. Texas has the most documented endemic species for this region, with 18 species, 7 of which are "microcaddisflies" (Hydroptilidae)(Appendix B). The most specioes families were Hydroptilidae, Hydropsychidae and Leptoceridae (Figure 4.20). These families represent 65% of the documented Texas caddisfly species from NHC records. Hydroptilidae accounts for 74 (34%) of the known Texas caddisfly species. While Hydroptilidae was represented by the most records from Texas (Figure 4.20) the most reported microcaddisfly was *Ochrotrichia tarsalis* with 68 records, none of the species from this family were in the top 5 most reported species from Texas. The top 5 species collected were *Smicridea fasciatella* (Hydropsychidae)(74), *Cyrnellus fraternus* (Polycentropodidae)(81), *Oecetis avara* (Leptoceridae)(81), *Chimarra obscura* (Philopotamidae)(139) and *O. inconspicua* (Leptoceridae)(180). These species represent 15% of the documented species, or 555 of the species records.

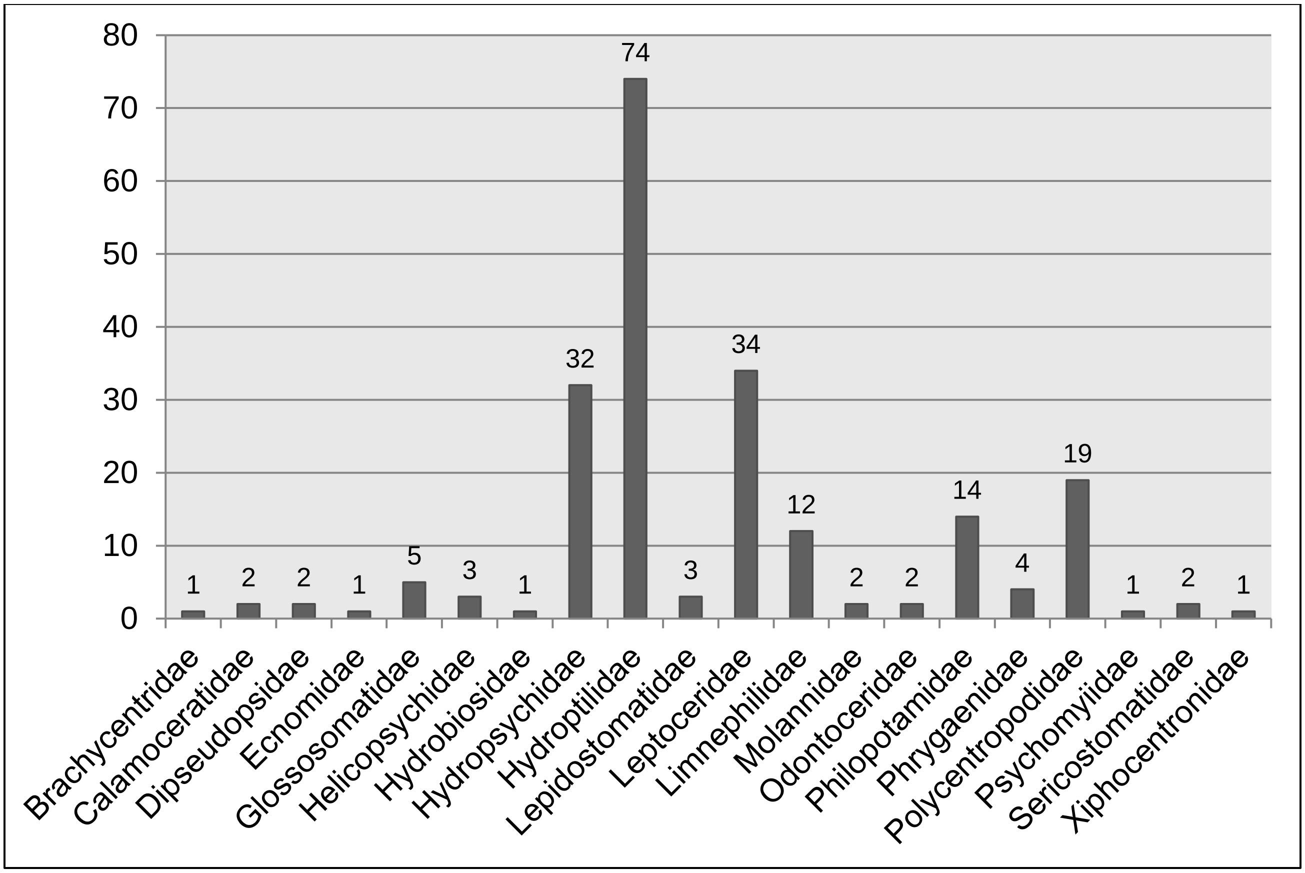


Figure 4.20: Number of species reported by family for Texas Trichoptera NHC records from 1900-2016. The most specioes families are Hydroptilidae, Hydropsychidae and Leptoceridae accounting for 65% of the documented species from Texas.

4.2 Additional Records from Published Peer Reviewed Literature

Additional records were gathered from published peer-reviewed literature that was documented in the *Distributional Checklist of Nearctic Trichoptera* by and Morse (2016)(Table 4.9). Published species distributions that were documented in Appendix B that only expanded a species distribution but were represented by NHC records from other states were not included in Table 4.9. No new families were documented from published literature; however two new genera were added from published accounts: *Parapsyche* and *Leptonema*. A total of 51 species were added to the over all species from the south-central United States. Table 4.9 shows the total number of species by state to include species whose distributions were new compared to NHC records, but the species was documented previously from NHC records. For example, Arkansas species increased by 14 additional species from published literature, however an additional 5 species (already documented in NHC baseline data) were added to Arkansas's species list because published literature accounts documented this state as part of their known distribution. Appendix C provides a list of genera or species that were documented via NHC records but were not corroborated through peer reviewed literature distributions.

New species were reported from only 14 of the 24 families recorded for this study. The family Hydroptilidae provided the bulk of new species with 10 species added via published literature accounts. Species accounts from New Mexico increased the most from published literature accounts, picking up an additional 19 species, increasing the known species from 118 to 137 (Appendix B). Texas represents the most species between NHC records and peer-reviewed literature additions with 222 species, or 49% of the species documented for the south-central Unites States.

Table 4.9: Species reported only from published literature accounts. Fourteen families had additional species not gathered via NHC records, a total of 45 additional species (total species by state and family). Note: the total number by family will not equal summation across states because some species may be represented in more than one state.

Family	AR	LA	NM	OK	TX	Total
Brachycentridae	1		1			2
Glossosomatidae			1			1
Hydropsychidae			1	1	1	3
Hydroptilidae	5	1	2	2	1	10

(table continues)

Family	AR	LA	NM	OK	TX	Total
Leptoceridae	2	1	2			4
Leptostomatidae			3			3
Limnephilidae	1	3	6			8
Molannidae				1		1
Philopotamidae					1	1
Phryganeidae					1	1
Ptilocolepidae				1		1
Rhyacophilidae	1		2		1	3
Thremmatidae	1		1			2
TOTAL	14	4	19	8	7	45

4.3 Heather A. Perry (HAP) Sampling Records from 2011-2016

Heather A. Perry (HAP) sampling for this project began during 2011 and ended in 2016, with a total of 65 locations sampled (Table 3.2 for detailed locations); included as part of the HAP sampling locations is material that was previously not identified from LSAM and EFNHC museums (Table 4.10). One hundred fifteen new sampling locations were added to the overall number of unique sampling locations from the south-central United States (Table 4.10).

Table 4.10: Sampling locations by state from HAP sampling 2011-2016. Previously unidentified material from LSAM (Louisiana State Arthropod Museum) and EFNHM (Elm Fork Natural History Museum) are included. A total of 115 sites were added and are broken into HAP samples = 65, LSAM = 16 and EFNHM = 34.

	AR	LA	NM	OK	TX	TOTAL
HAP		25	10	4	26	*65*
LSAM		13	1		2	*16*
EFNHM	1	1		4	28	*34*

HAP samples totaled 923 additional records, with 651 identified to species. The additional 115 sampling locations expanded all but Arkansas percent counties sampled (Table 4.11). With the inclusion of new counties/parishes sampled during the HAP Sampling, there was no change in percent coverage for Arkansas. Louisiana had the most new parishes sampled increasing the state coverage to 61%. New Mexico and Oklahoma had low number of new counties sampled; therefore increased state coverage was minimal. Twenty-six counties were sampled in Texas, with only 4 newly sampled counties. Even with this large number of sampled counties in comparison to the other states the overall state coverage is still lower than the rest of the states. However, if the total number of counties/parishes for the study area is evaluated of which there are 503, Texas counties account for 51% of the total number of counties within the study area. The total number of counties/parishes sampled is 297, or 58% of the study area. When compared by total number of counties to total number sampled by state, Texas has the most coverage for the study area.

Table 4.11: Total number of counties/parishes by state and the total number of counties/parishes for study area. Number of counties/parishes covered for both NHC and HAP sampling and the percent coverage broken down by state and total coverage.

State	# Counties	# HAP Counties	# Added	# Sampled	% Coverage	% Coverage for study
AR	75	1	0	65	87	13
LA	64	16	5	39	61	8
NM	33	8	2	26	79	5
OK	77	3	1	41	53	8
TX	254	26	4	122	48	24
Total	503			293		58%

The most collected families were Hydropsychidae, Hydroptilidae and Leptoceridae representing 76% of HAP records from 2011-2016, with Hydroptilidae as the most collected family (33%)(Figure 4.21). The most specioes family was Hydroptilidae totaling 43% of the 108 species identified from HAP 2011-2016 sampling (Figure 4.22).

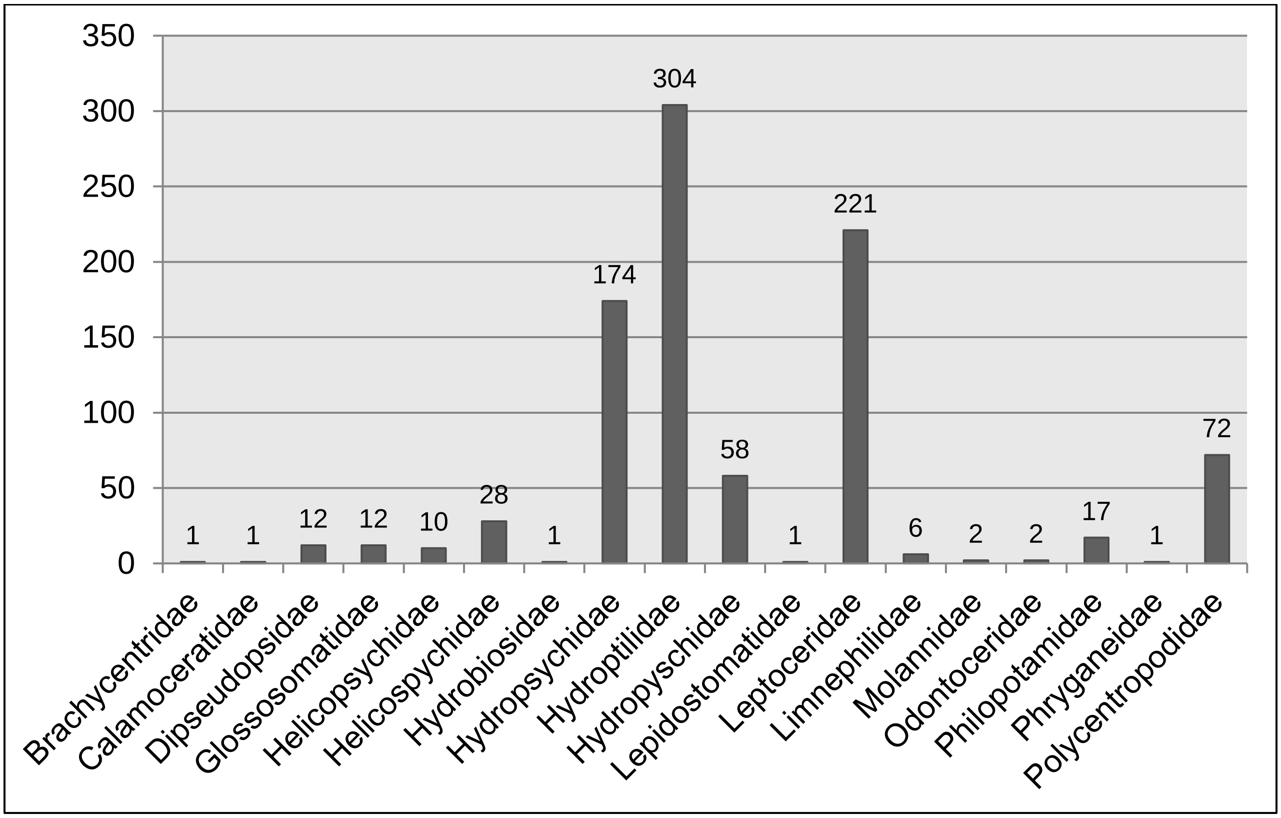


Figure 4.21: Number of records by family collected during HAP sampling from 2011-2016. Hydroptilidae was the most collected family representing 33% of the total records. The top 3 sampled families (Hydropsychidae, Hydroptilidae and Leptoceridae) make up the bulk of the records, accounting for 76% of the total 923 records.

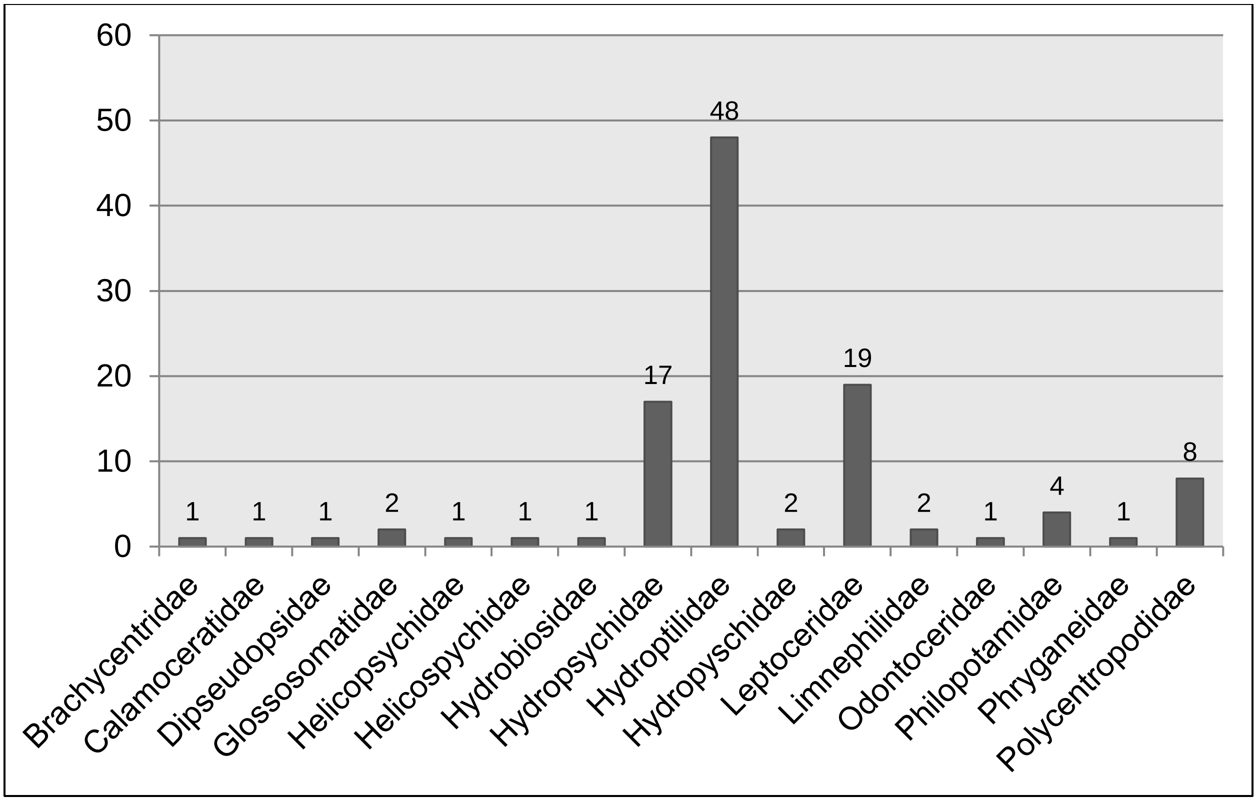


Figure 4.22: Number of species identified by family for HAP sampling from 2011-2016. Hydroptilidae was the most specioes family with 48 identified species.

HAP samples processed and identified contained 49,269 caddisflies totaling 16 families, 40 genera and 108 species (Table 4.12). Only 29,673 individuals were identified to species, the majority of individuals not identified past family or genus were females. Texas had the majority of caddisflies identified, 69%, from 28 locations, and therefore the highest number of documented species (Table 4.12). Six species had more than 1,000 individuals identified to species and are listed in Table 4.13. Five were Hydropsychidae species, and represent 19,258 individual caddisflies or 65% of the total species identifications. While Hydroptilidae was the most specioes family no species from this family was collected in the top 6-caddisfly species by total number of individuals. However, *Oxyethira janella* (Hydroptilidae) was the most collected micro-caddisfly with 952 individuals. The species with the greatest number of records was

Oecetis inconspicua (Leptoceridae), which was recorded from 38 records but only with 263 individuals.

Table 4.12: HAP caddisfly sampling records (2011-2016) breakdown of total records and sample demographics by state; total of 923 records from 115 sampling locations were added to baseline data for the south-central United States. One hundred eight species from 16 families and 40 genera were identified from 2011-2016.

Record Description	Total
Total HAP Records	923
ID only to Family	132
ID only to Genus	141
ID to Species	650
New Records for AR	8
New Records for LA	192
New Records for NM	52
New Records for OK	64
New Records for TX	607
# Families Identified	16
# Genera Identified	40
# Species Identified	108
# Species for AR	5
# Species for LA	36
# Species for NM	19
# Species for OK	22
# Species for TX	82
# Individuals Collected	49,269
# Individuals ID to species	29,673
# Individuals for AR	34
# Individuals for LA	1,416
# Individuals for NM	7,073
# Individuals for OK	589
# Individuals for TX	20,558

Table 4.13: Species with the most number of collected individuals and the number of records that each species was reported from. The majority of caddisflies were Hydropsychidae species totaling 19,258 individuals of the 29,673 individuals identified to species (65%).

Family	Species	# of Specimens	# of Records
Leptoceridae	*Oecetis avara*	1,071	29
Hydropsychidae	*Cheumatopsyche lasia*	1,358	17
Hydropsychidae	*Hydropsyche alvata*	1,410	30
Hydropsychidae	*Cheumatopsyche analis*	5,038	25
Hydropsychidae	*Smicridea fasciatella*	5,612	21
Hydropsychidae	*Cheumatopsyche camypla*	5,540	4

As previously discussed 411 species were documented from NHC records, and published species accounts added an additional 51 species. After accounting for invalid or synonymized taxonomy the grand total of species is 452. HAP sampling that occurred between 2011-2016 expanded known species lists for Louisiana, New Mexico, Oklahoma and Texas by 7,7,1 and 3 species, respectively. However, only 2 species were new to the south-central United States: two Hydroptilidae (identified by S.C. Harris Clarion University of Pennsylvania, Clarion, Pennsylvania) *Hydroptila scheiringi* (Louisiana) and *Mayatrichia tuscaloosa* (Texas). The addition of these 2 new species brings the known species from the south-central United States to 454.

4.4 Caddisfly Demographics: for Study Area and by State

The combination of data from NHC records HAP records from 1900-2016 results in a total of 13,352 records and a conservative estimate of total individuals of 161,241

(Table 4.14) from 1,915 sampling locations (Figure 4.23). The conservative estimate of total number of individuals is due to some records not having a total number of individuals listed so a total of 1 was assumed.

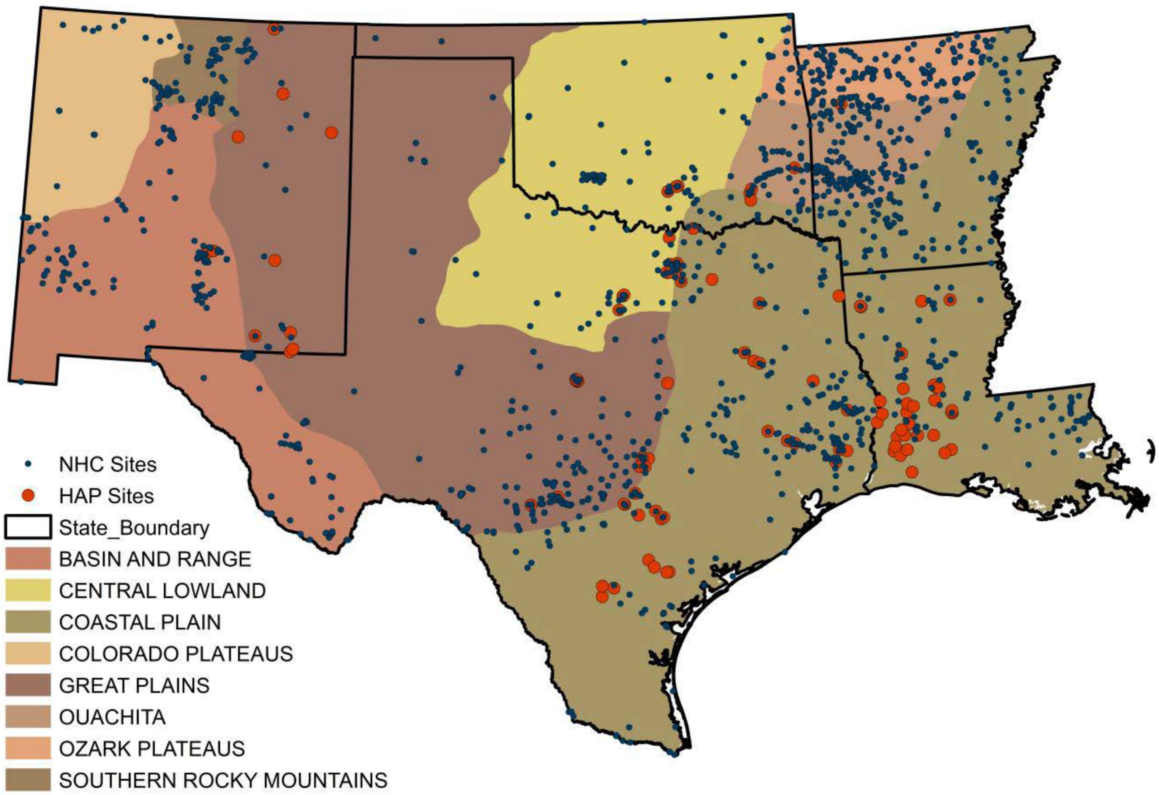


Figure 4.23: Sampling locations for the south-central United States gathered from HAP sampling (115) and NHC records (1,800). A total of 1,915 unique sampling locations are depicted by physiographic provinces.

One issue in utilizing NHC records is the inability to document sampling effort. Subsequent users of this data cannot ascertain the duration of the sampling event from the limited data provided either on museum labels or within electronic databases. This limitation leaves users with the inability to document if the low number of species for a location is due to depauperate species populations, species reported were incidental catch for another project, or if more material was collected but never identified. For these reasons (and possibly others) Figure 4.24 illustrates how skewed species records are for the south-central United States by location. Seventy-three percent of unique sampling locations reported 1-4 species (1,272 locations). Ten or more species were only reported from 237 locations, and using the natural breaks in the data only 10 locations reported 35 or more species. Locations where 12 or more species were collected tend to be from scenic areas of the south-central United States, with areas in the panhandle of Texas and Oklahoma, as well as eastern New Mexico lacking sampling efforts. Lack of samples in some of these areas could be attributed to the ephemeral nature of headwater streams and rivers and local water quality parameters.

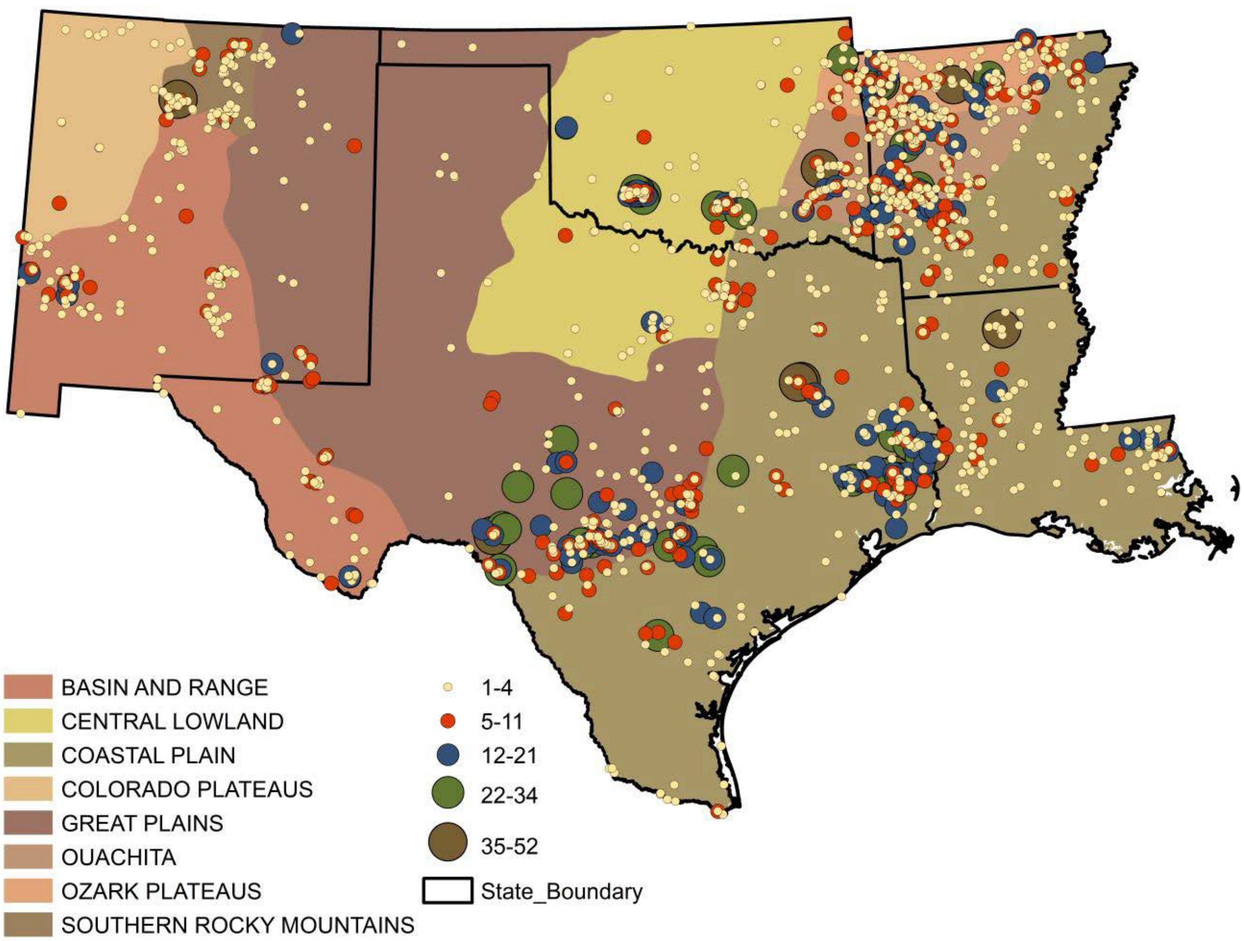


Figure 4.24: Sampling locations by physiographic province are represented by graduated species symbols to illustrate the number of species reported by location. This maps illustrates areas of higher sampling efforts, as well as un-even sampling efforts and or at least the inability to document sampling efforts from historic NHC records where only presence of a species is reported.

4.5 Sampling Demographics by Family and Species

Hydropsychidae was the most collected family by both the number of records (3,440) and the total number of individuals (62,151) and represented 26% of records and 39% of the total number of caddisflies (Table 4.18). The top three families collected throughout this study have been Hydropsychidae, Hydroptilidae and Leptoceridae, and overall they represent 8,805 or 66% of the total number of records, and 77% (123,856) of the total number of individual caddisflies recorded for this study (Table 4.14). *Oecetis inconspicua* (Leptoceridae) was the most reported species by number of total records (455) making up only 4% of the total number of records identified to species (11,204). *Cheumatopsyche campyla* (Hydropsychidae) was the species that was collected in the highest abundance, with 8,889 individuals or 7% of caddisfly individuals. The top 3 species collected are all from the family Hydropsychidae and represent 18% of individuals collected: *Cheumatopsyche analis* (6,637), *Smicridea fasciatella* (7,172) and *C. campyla.*

Table 4.14: Total records combined from NHC's and HAP sampling from 1900-2016. A total of 12,426 records and 161,241 individuals were documented. The most abundant families in number of records and individuals were Hydropsychidae, Hydroptilidae and Leptoceridae.

Family	Total # Records	Total # Individuals
Apataniidae	1	10
Brachycentridae	75	384
Calamoceratidae	47	332
Dipseudopsidae	71	317
Ecnomidae	19	53
Glossosomatidae	381	4,888
Helicopsychidae	374	4,456
		(table continues)

Family	Total # Records	Total # Individuals
Hydrobiosidae	35	258
Hydropsychidae	3,440	62,151
Hydroptilidae	2,478	39,509
Lepidostomatidae	135	655
Leptoceridae	2,887	22,196
Limnephilidae	520	2,010
Molannidae	83	244
Odontoceridae	87	605
Philopotamidae	1,095	11,604
Phryganeidae	98	741
Polycentropodidae	1,073	7,848
Psychomyiidae	170	7,848
Rhyacophilidae	157	430
Sericostomatidae	42	411
Thremmatidae	68	591
Xiphocentronidae	13	55
TOTAL	13,352	161,241

Table 4.15 breaks down by state the most collected family and species by number of records and number individuals that were identified to species. The total number of records that were identified to species was 11,204 (84%) with 77% (123,870) species identification rate. The families reported by the highest number of records by state in total represent 27% of the records identified to species, and 35% of the total number of individuals that were identified to species. Hydropsychidae was the most collected family by both number of records and number of total individual caddisflies for Arkansas, Louisiana, New Mexico and Oklahoma. The Texas caddisfly family most commonly reported in records and with the largest total number of individuals was Hydroptilidae.

Table 4.15: Combined records from NHC's and HAP sampling from 1900-2016, parsed into most collected family and species by number of records (Rec) and number of individuals (# Ind) by state. This represents records identified to species with a total number of records of 11,204 and total number of individuals 123,870.

State	Family	Rec	# Ind	Species	Rec	Species	# Ind
AR	Hydropsychidae	766	8,846	*Ochrotrichia anisca^*	138	*Diplectrona modesta**	2,364
LA	Hydropsychidae	259	1,648	*Cheumatopsyche pinaca**	55	*Hydropsyche alvata** *Oecetis inconspicua~*	346 ea
NM	Hydropsychidae	253	9,728	*Hesperophylax occidentalis+*	57	*Cheumatopsyche campyla**	5,926
OK	Hydropsychidae	657	8,294	*Cheumatopsyche campyla**	139	*Cheumatopsyche campyla**	2,213
TX	Hydroptilidae	1,138	16,632	*Oecetis inconspicua~*	196	*Smicridea fasciatella**	6,584
Total		3,073	45,148		585		17,779

* denotes a species from the family Hydropsychidae; ^ denotes a species from the family Hydroptilidae; ~denotes a species from the family Leptoceridae; +denotes a species from the family Limnephilidae

Species that were most commonly collected by state were from four families: Hydropsychidae, Hydroptilidae, Leptoceridae and Limnephilidae. Five species of Hydropsychidae were reported as either the species with the most number of total records or the species with the most number of individual caddisflies. While most states had different species that represented the species with either the most number of records or number of individuals, *Cheumatopsyche campyla* was the species that fit both of these criteria for Oklahoma. The Louisiana species with the most abundantly collected species by number of reported individuals was 346 for both *Hydropsyche alvata* and *Oecetis inconspicua*, or a total of 692 individuals. The 5 species, which were reported with the most number of individuals by state, represent 17,779 individuals and 14% of individuals identified to species. *Smicridea fasciatella* represents the bulk of these 17,779 individuals totaling 6,584 (37%) of the most abundant species collected from NHC records or HAP sampling.

4.6 New Species Records and Range Expansions

For several species, natural history collection records for the south-central United States confirmed distributions only gathered from peer reviewed literature. In some cases, new distributions were documented from NHC records but these records have not been confirmed and should be used with caution. Appendix B provides a checklist of species obtained from multiple sources for this study. HAP sampling (2011-2016) added 2 additional species to the south-central United States checklist; *Mayatrichia tuscaloosa* and *Hydroptila scheiringi*.

4.6.1 *Mayatrichia tuscaloosa* (Hydroptilidae)

Mayatrichia is one of two genera in the tribe Neotrichiini and this tribe of micro-caddisflies is only found in the New World (Wiggins 1996). One male specimen of *Mayatrichia tuscaloosa* (Figure 4.25) was collected from Travis Co. using a UV black light trap in 2014 from Bull Creek located in Saint Edwards Park in Austin, Texas and was identified by Dr. S.C. Harris (Clarion University of Pennsylvania, Clarion, Pennsylvania). The species was first described by Harris and Sykora from Alabama in 1996 from a single specimen; this record was included in a recent publication documenting this species new distribution records by Harris and Flint (2016), as well as 2 males collected in Neuvo Leon, Mexico in 1976. This species is one of 3 species of *Mayatrichia* that are known to have Neotropical distributions (Holzenthal and Calor 2017).

Figure 4.25: Location of *Mayatrichia tuscaloosa* from Bull Creek at Saint Edwards Park in Travis Co., Texas.

4.6.2 *Hydroptila scheiringi* (Hydroptilidae)

The genus *Hydroptila* is in the sub-family Hydroptilinae and tribe Hydroptilini. This tribe consists of three other genera: *Agraylea, Oxyethira* and *Paucicalcaria*. One male specimen was collected from Six Mile Creek, west of Pitkin, Louisiana in Vernon Parish (Figure 4.26) using a UV black light trap in 2015 and was identified by Dr. S.C. Harris (Clarion University of Pennsylvania, Clarion, Pennsylvania). This species, first described by Harris in 1986 from Baldwin County, Alabama, has since been reported from Wakula Co., Florida in 2009 by Harris et al. (2012) and Congaree Swamp National Park in Richland County, South Carolina (Pescador et al. 2004).

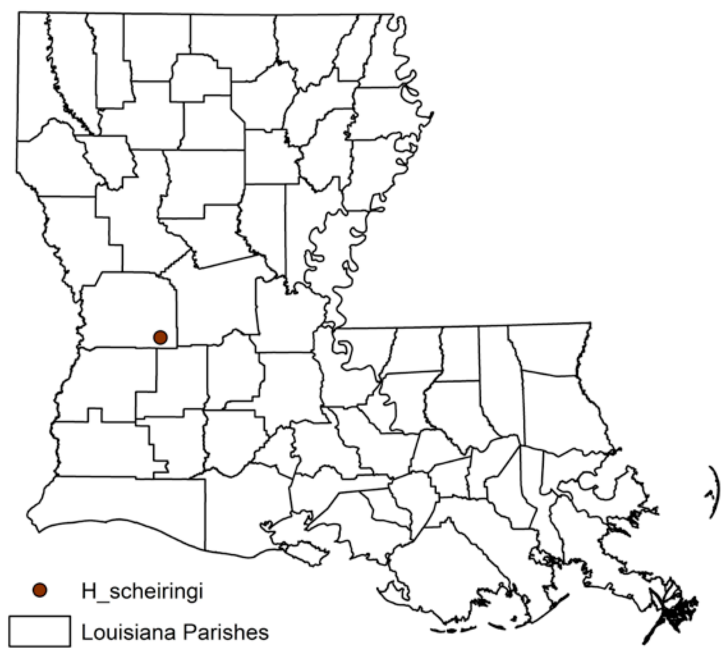


Figure 4.26: Location of *Hydroptila scheiringi* from Six Mile Creek, near Pitkin, Louisiana in Vernon Parish.

4.6.3 Expanded Species Ranges

Sixteen families with a total of 78 species have expanded ranges documented through NHC records or HAP sampling. HAP Species distributions were verified by

Trichopteran experts. Appendix C provides the associated historic NHC records or HAP records that were used for new distribution locations. Prior published distributions are associated with each species and that are reported in Rasmussen and Morse (2016). Four families dominate the total number of species with expanded ranges: Hydropsychidae, Hydroptilidae, Leptoceridae, and Polycentropodidae (67%).

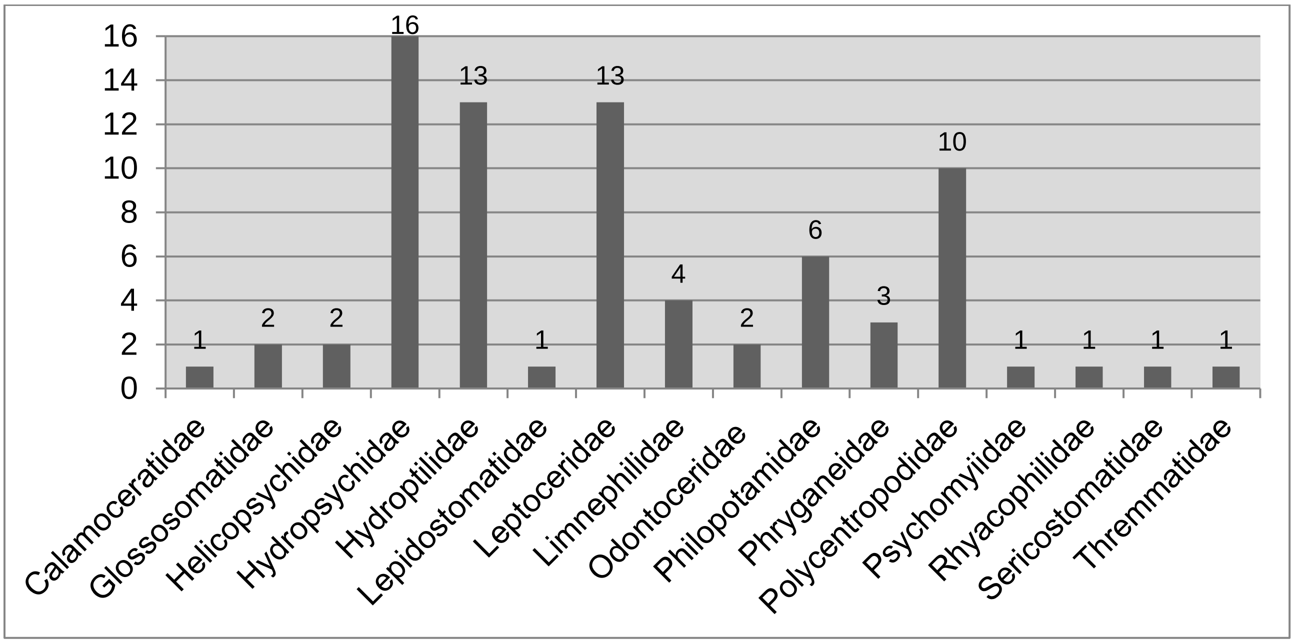


Figure 4.27: Number of species by family that have expanded ranges previously not published from historic NHC or HAP sampling.

Total number of new species distributions by state is shown in Figure 4.28. Louisiana and New Mexico account for 60% of the new species distributions. Five species: *Cheumatopsyche analis* (NM, OK)*, C. harwoodi* (AR, OK)*, Hydropsyche placoda* (AR, LA)*, H. incommoda* (OK, TX)*,* and *Ceraclea protonepha* (AR, OK) have new distributions from 2 states (these numbers are reflected in Figure 4.28). Eleven NHC's provided 94 previously non-published distributions; 9 records from HAP documented new distributions from 2011-2016 sampling efforts (Table 4.16). INHS provided the most number of new distribution records by NHC's (32%).

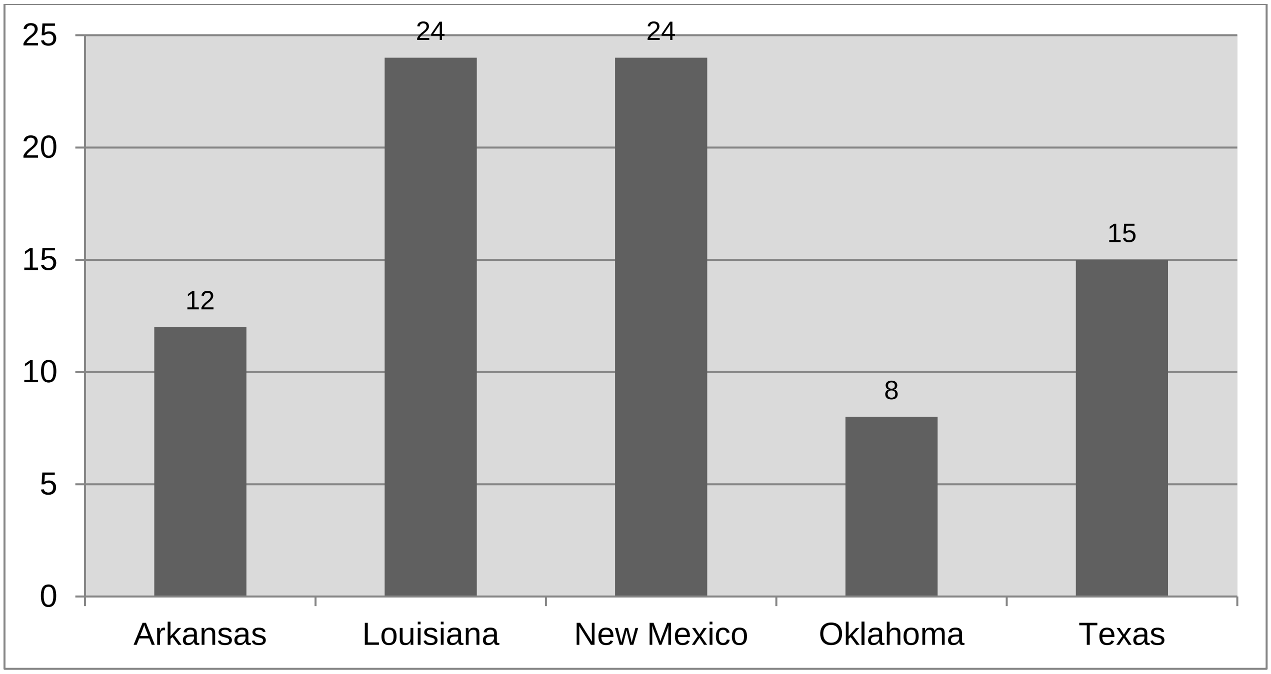


Figure 4.28: Total number of species with new record distributions by state that were acquired from NHC's or HAP 2011-2016 sampling, five species have distributions in 2 states. Sixty percent of new distribution records are from Louisiana and New Mexico.

Table 4.16: Number of records provided by NHC or HAP documenting new species distributions in the south-central United States. The INHS provided the most new distribution records (32%).

NHC	# of Records
Clemson University (CLM)	11
Colorado State University (CSU)	2
David E. Ruiter (DER)	19
Elm Fork Natural History Museum (EFNHM)	8
Global Biodiversity Information Facility (GBIF)	3
Heather A. Perry (HAP)	9
Illinois Natural History Survey (INHS)	30
Louisiana State Arthropod Museum (LSAM)	9
Stephen R. Moulton (SRM Coll)	5
Texas A&M University (TXAM)	1
University of Arkansas (UAR)	2
University of Minnesota, Saint Paul (UMSP)	4
TOTAL	103

4.7 Endemic Species

Using NHC records, published accounts, and HAP sampling 18 endemic species were documented from 8 families for the south-central United States (Figure 4.29). Endemic species account for only 4% of the species documented from this region. The family with the most documented endemic species is Hydroptilidae (33%), and the state with the highest occurrence of endemic species is Texas accounting for 50% of the endemic species from the south-central United States (Figure 4.30). However, the endemic species in Texas represent 4% of the 215 species documented within the state. Four families are represented by one endemic species and Oklahoma has no documented endemic species (Figure 4.30).

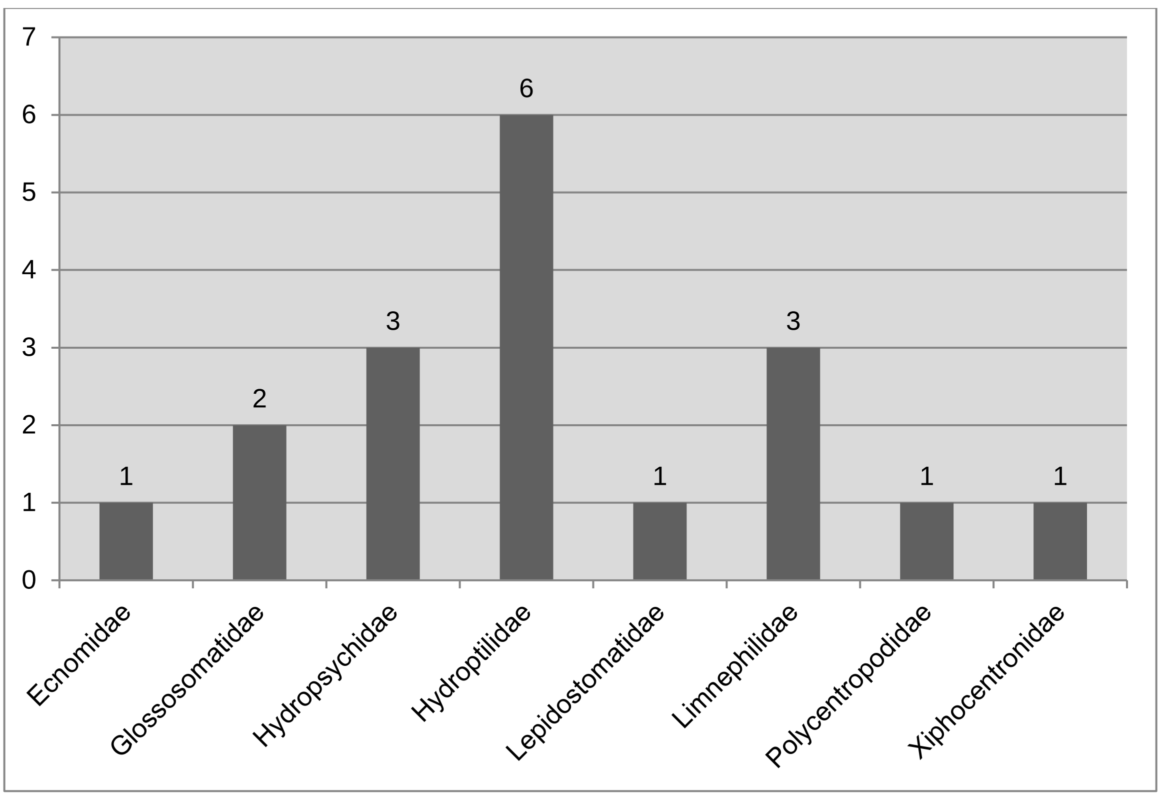


Figure 4.29: Eighteen species of endemic caddisflies documented from the south-central United States and represent 8 families. One third of the endemic species are Hydroptilidae “micro-caddisflies”.

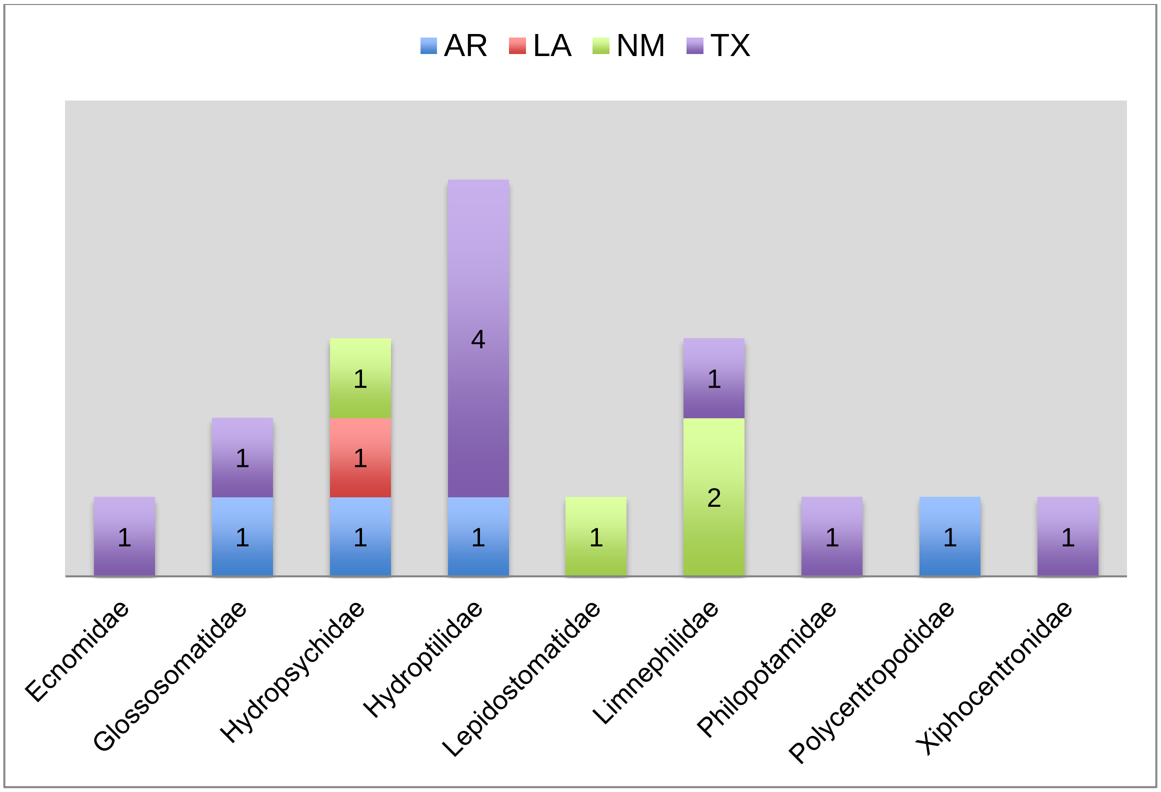


Figure 4.30: Endemic species of caddisflies represented with stacked bars giving the total of species by family and state. Texas has the most endemic species (9) and 44% are Hydroptilidae "microcaddisflies".

Table 4.17 provides the endemic species by state; (*) indicates that a species is not only endemic but a species of concern with either the U.S. Fish and Wildlife Department (USFW) or a state agency (further discussed in Section 4.7). The following endemic species were not reported through NHC records or HAP sampling efforts, but were documented through published literature.

- Lepidostomatidae: *Lepidostoma deceptivum* (NM) (Banks 1907, Weaver 1988, Weaver 2002).
- Limnephilidae: *Homophylax adriana* (NM) (Denning 1964); *Limnephilus chavas* (NM) (Nimmo 1991).

Table 4.17: Endemic species listed by state; (*) indicates this species is of concern with either federal or state agencies.

Family	Species	State
Ecnomidae	*Austrotinodes texensis**	Texas
Glossosomatidae	*Agapetus medicus**	Arkansas
	*Protoptila arca**	Texas
Hydropsychidae	*Cheumatopsyche robisoni*	Arkansas
	*Diplectrona rossi**	Louisiana
	Hydropsyche vanaca	New Mexico
Hydroptilidae	*Hydroptila abbotti*	Texas
	*Neotrichia juani**	Texas
	*Neotrichia sonora**	Texas
	Ochrotrichia boquillas	Texas
	*Ochrotrichia guadalupensis**	Texas
	*Paucicalcaria ozarkensis**	Arkansas
Lepidostomatidae	*Lepidostoma deceptivum*	New Mexico
Limnephilidae	*Homophylax adriana*	New Mexico
	*Limnephilus adapus**	Texas
	Limnephilus chavas	New Mexico
Polycentropodidae	*Polycentropus stephani*	Arkansas
Xiphocentronidae	*Xiphocentron messapus**	Texas

Distribution maps by physiographic section for the following endemic species are in Appendix D. Endemic species from Arkansas, documented via NHC records, included *Agapetus medicus* and *Cheumatopsyche robisoni*, both of these species had a relatively large number of collection locations, 33 and 27, respectively; *Paucicalcaria ozarkensis* and *Polycentropus stephani* were both reported from ≤ 5 sites. The majority of endemic species from Arkansas were collected are from western Arkansas in the Ozark Platueaus and Ouachita physiographic provinces. More specifically, the physiographic section with the highest endemism is the Ouachita Mountains.

Diplectrona rossi is the only endemic species documented in Louisiana and is reported from Jackson Parish in the north-central region from only two NHC records. Louisiana is located with in the coastal plain physiographic province, but the use of physiographic sections of Louisiana places these records within the West Gulf Coastal plain.

Hydropsyche vanaca was documented from New Mexico through the aid of NHC records. This species was collected from the Great Plains physiographic, specifically the High Plains physiographic sections in the northeastern portion of the state.

Eleven species from Texas locations were documented through the use of NHC records. The remaining two species, *Neotrichia juani*, and *Protoptila arca* have records from NHC as well as from HAP sampling during 2011 and 2014. *Austrotinodes texensis*, *A. erigia*, and *Xiphocentron messapus* were all reported from >10 locations; the following species have >5 records each: *N. juani*, and *Ochrotrichia guadalupensis*; the species with < 5 documented locations are *Hydroptila abbotti*, *Limnephilus adapus*, *N. sonora*, *Ochrotrichia boquillas*, and *P. arca*. Ten of Texas's endemic species are from the Great Plains province, specifically the Edwards Plateau, however a few of these species have ranges that extend into the Coastal Plain province and both Central Texas and West Gulf Coast Plain sections. *H. abbotti* and *P. arca* are from the Coastal Plain, specifically the West Gulf Coast Plain physiographic section. The Mexican Highlands of the Basin and Range province are where *L. adapus* and *O. boquillas* were collected; *N. sonora* is primarily from this same area but can have range extension into the Edwards Plateau. Lastly, *O. guadalupensis* has a very restrictive range to the border region between the Basin and Range and Great Plains. The border of these provinces is at the division of the Sacramento and Pecos Valley physiographic sections.

4.8 Species of Concern

A total of 30 species are listed as species of concern or in need of more information by state and federal agencies (Table 4.18). The United States Fish and Wildlife Service (USFW) has 98 species of caddisfly that fall within a series of federal listing status categories, 11 of these species are within this study area. While these species are not federally listed the majority of them have been petitioned or considered as a candidate for listing as a threatened or endangered species in 1994 (USFW 2017). Two USFW species, *Protoptila arca* and *Hydroptila ouachita* were both listed in 2009 as having partial 90-day findings as threatened or endangered with critical habitat as part of a petition to list 475 species in the southwestern United States (USFW 2017).

Texas Parks and Wildlife Department (TPWD) lists 18 caddisfly species of greatest conservation need (SGCN) and are under the umbrella of the 2011 Texas Conservation Action Plan (TPWD 2017b). Eleven species are listed at the state rank of S1 “critically imperiled” referring to the rarity and possible vulnerability of populations to local or state extirpation: *Cheumatopsyche morsei, Chimarra holzenthali, Hydroptila ouachita, Limnephilus adapus, Neotrichia juani, N. mobilensis, N. sonora, Ochotrichia guadalupensis, Phylocentropus harrisi, Protopila arca* and *P. balmorhea.* The remaining 7 species are listed as “imperiled”, or S2 state rank, which is defined as being imperiled at the national, state/province level due to the rarity or restricted habitat range, < 20 known populations, or other factors that makes the species susceptible to extirpation:

Austrotinodes texensis, Hydroptila melia, Nectopsyche texana, Ochotrichia capitana, Oxyethira ulmeri, Wormaldia arizonensis and *Xiphocentron messapus* (TPWD 2017b).

Table 4.18: Species of concern and the agency that lists each species. Abbreviations are as follows: USFW (United States Fish and Wildlife Department); TPWD (Texas Parks and Wildlife Department); LDWF (Louisiana Department of Wildlife and Fisheries); ANHC (Arkansas Natural Heritage Commission). Species (*) are endemic and are listed in Section 4.6.

Family	Species	Agency
Dipseudopsidae	*Phylocentropus harrisi*	TPWD
Ecnomidae	*Austrotinodes texensis**	USFW, TPWD
Glossosomatidae	*Agapetus medicus**	USFW, ANHC
	*Protoptila arca**	USFW, TPWD
	Protoptila balmorhea	USFW, TPWD
Helicopsychidae	*Helicopsyche paralimnella*	USFW
Hydropsychidae	*Diplectrona rossi**	USFW, LDWF
	Cheumatopsyche morsei	USFW, TPWD, LDWF
Hydroptilidae	*Hydroptila melia*	TPWD
	Hydroptila molosonae	LDWF
	Hydroptila poirrieri	LDWF
	Hydroptila ouachita	USFW, TPWD, LDWF
	*Paucicalcaria ozarkensis**	ANHC
	*Neotrichia juani**	TPWD
	Neotrichia mobilensis	TPWD
	*Neotrichia sonora**	TPWD
	Ochrotrichia capitana	TPWD
	Ochrotrichia contorta	ANHC
	*Ochrotrichia guadalupensis**	TPWD
	Ochrotrichia robisoni	ANHC
	Oxyethira ulmeri	TPWD
Lepidostomatidae	*Lepidostoma morsei*	USFW

(table continues)

Family	Species	Agency
Leptoceridae	*Ceraclea spongillovorax*	LDWF
	Nectopsyche texana	TPWD
Limnephilidae	*Limnephilus adapus**	TPWD
Philopotamidae	*Chimarra holzenthali*	USFW, TPWD, LDWF
	Wormalidia arizonensis	TPWD
Psychomyiidae	*Paduniella nearctica*	USFW, ANHC
Sericostomatidae	*Agarodes libalis*	LDWF
Xiphocentronidae	*Xiphocentron messapus**	TPWD

The Louisiana Department of Wildlife and Fisheries currently has 8 caddisfly species on their Rare Animal List (2017). Six species: *Agarodes libalis, Cheumatopsyche morsei, Chimarra holzenthali, Diplectrona rossi, Hydroptila ouachita,* and *Hydroptila molsonae* are state ranked as S1 which lists species as “critically imperiled” due to extreme rarity where 5 or fewer extant populations are known or some variable causing the species to be vulnerable to extirpation (LDWF 2017). The remaining species: *Ceraclea spongillovorax* and *Hydroptila poirrieri* are ranked as S2 and this is defined as “imperiled” and have documented 6-20 known extant populations or are vulnerable to extirpation due to some factor(s) (LDWF 2017).

Arkansas Natural History Commission lists 5 species of caddisflies on its state conservation site. Three species are listed at the S1 rank: *Paduniella nearctica, Paucicalcaria ozarkensis,* and *Ochrotrichia robisoni*. This rank is defined as “extremely rare” with 5 or fewer occurrences in the state, or a low number or remaining individuals, and may be vulnerable to local extirpation (ANHC 2017). The remaining two species: *Agapetis medicus* and *Ochrotrichia contorta* are given the label SNR, meaning that they are not ranked yet (ANHC 2017).

4.9 Neotropical Species at Their Greatest Extent of Documented Ranges

Ten neotropical species from 6 caddisfly families are at their greatest range extension in the south-central United States. Hydroptilidae (4) and Hydropsychidae (2) make up 60% of these species, the remaining families contain only one species each (Figure 4.31). Species are only documented from New Mexico and Texas, with the majority (80%) of the species being reported from Texas (Table 4.19). The most specioes family is Hydroptilidae with *Hydroptila* being the most specioes genera within this family. One species was only recorded through published literature and not through NHC records or HAP sampling efforts: Hydropsychidae: *Leptonema albovirens* (TX) (Flint 1968, Wiggins 1977, Bueno-Soria and Flint 1978).

Two neotropical species were documented at their greatest range from New Mexico: *Marilia mexicana* and *Hydroptila denza*. *M. mexicana* was documented from New Mexico through the aid of NHC records, while *H. denza* was collected in HAP sampling during 2015 in Quay County with both species represented by a single collection record. *H. denza* were collected from the Pecos Valley in the Great Plains physiographic province. *M. mexicana* was reported from the Sacramento section of the Basin and Range physiographic province.

Five neotropical caddisfly families are represented by 8 species in Texas. All of these species were collected in the Great Plains physiographic province. The majority of these species were collected from the Edwards Plateau, Central Texas, and West Gulf Coastal Plain physiographic sections. Two species, *Atopsyche erigia* and *Chimarra beameri*, were collected during HAP sampling efforts in 2011 and 2014. *C. beameri* and *Polyplectropus santiago* had the highest number of collection locations, 31 each.

Hydropsyche delrio and *Hydroptila potosina* were reported from >5 records; while *Neotrichia caxima* and *Hydroptila acuminata* was reported from < 5 documented records.

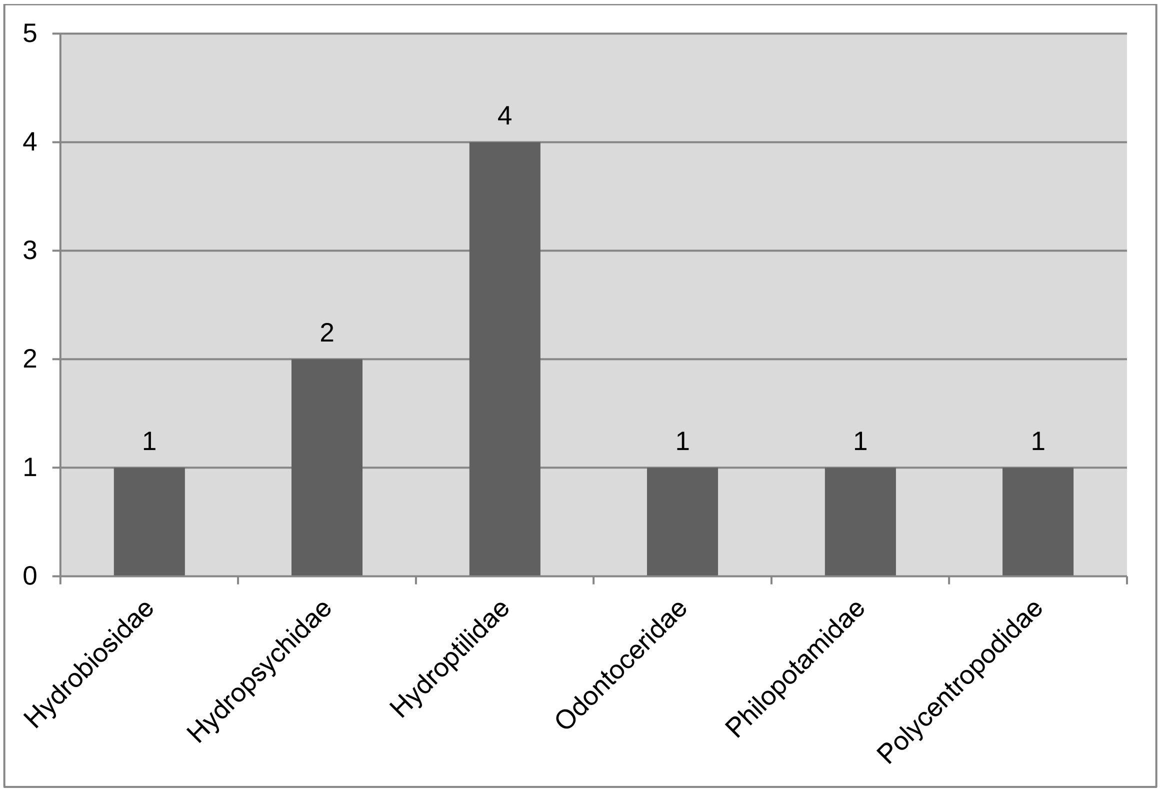


Figure 4.31: Neotropical caddisfly species at their greatest range extension by family. A total of 10 species from 6 families were documented from the south-central United States. Hydroptilidae represents the family with the highest number of species at their greatest range extension.

Table 4.19: Ten neotropical species from 6 families are at their greatest extent of their documented range. The state they are documented from is the only state within the United States they are known from.

Family	Species	State
Hydrobiosidae	*Atopsyche erigia*	Texas
Hydropsychidae	*Hydropsyche delrio*	Texas
	Leptonema albovirens	Texas

(table continues)

Family	Species	State
Hydroptilidae	*Hydroptila acuminata*	Texas
	Hydroptila denza	New Mexico
	Hydroptila potosina	Texas
	Neotrichia caxima	Texas
Limnephilidae	*Marilia mexicana*	New Mexico
Philopotamidae	*Chimarra beameri*	Texas
Polycentropodidae	*Polyplectropus santiago*	Texas

4.10 Biogeographic Region Structure Based on Geographic Variables

4.10.1 Determination of the Minimum Number of Species for Community Structure NMDS and ANOSIM Analyses

The species count that maximized the relation between caddisfly community structure and geographic variables was identified through the use of ANOSIM Global R values. Evaluation of NMDS plots was contingent upon statistical significance as well as visual representation. A future goal of this study is to produce a regional atlas, and clear visual repetition of geographic separation between caddisfly communities is an important factor in species mapping.

Several geographic variables scored Global R values of 0.5 or greater with a minimum of 8+ species and with a total of 289 sites utilized for these analyses, or 17% of the total data set (Table 4.20). However, interpretation of NMDS plots at a minimum species number of 8 was difficult due to the crowding and mixing of individual points. As the minimum number of species required to be in the analysis increased the number of sites decreased and the NMDS plots became clearer; the segregation of species community structure by geographic variables and ANOSIM Global R values increased as the minimum number of species increased (Table 4.20).

Table 4.20: PRIMER-E NMDS ANOSIM outputs for sites that contain 8+, 10+, 11+, 12+ and 15+ species. Each ANOSIM was run for 99,999 (p=0.00001) permutations for each geographic variable. Global R statistics, the statistical significance and the number of permutations that were greater than or equal to the global R statistic are provided. The number of sites used for each ANIOSM permutation is provided. Two variables, Eco Region Level I and Avg Precipitation consistently had the lowest global R statistic, while HUC 4 watershed eco variable had the highest global R statistic for each species treatment.

Geo Var	Global R				
Eco Region Level I	0.350	0.323	0.329	0.336	0.333
Eco Region Level II	0.514	0.571	0.594	0.614	0.673
Physio division	0.469	0.519	0.548	0.571	0.656
Physio provinces	0.456	0.498	0.529	0.558	0.652
Physio Sections	0.520	0.564	0.572	0.607	0.668
Avg Precipitation	0.227	0.234	0.245	0.221	0.225
HUC 4 Watershed	0.553	0.610	0.626	0.651	0.689
# Species	8+	10+	11+	12+	15+
# Sites	289	239	206	176	129

For the hypotheses described in sections 4.9.2 – 4.9.4 the minimum number of species by site was set at 10+, utilizing 239 sites or 14% of the total sites. While analyses at 10+ species are not as clear as those at 15+, the minimum of 10+ species produced clear groupings of geographical factors on NMDS plots while maximizing the number of sites that could be effectively used. Furthermore, the ANOSIM Global R values reported for most of the geographical factors was ~0.5 or greater. Regardless of the minimum number of species used, HUC 4 variable consistently had the highest Global R values, while average annual precipitation had the lowest Global R values (Table 4.20); this is discussed in a subsequent section.

4.10.2 Ho_1. Caddisfly Communities in the South-Central United States are not Distributed along Precipitation Gradients

Average annual precipitation ranges were used to delineate community structure across the study area. Using 10+ species the ANOSIM Global R was 0.234 (p=0.00001 for 9,999 permutations), which suggests community structure is related to annual precipitation and not the product of random assortment. The R-value for annual precipitation was relatively weak in comparison to other geographic factors, but groupings based on 41-70, 21-40, and 20 inches or less average annual precipitation are apparent (Figure 4.32). These grouping likely correspond to other geographic factors - when compared to an NMDS of physiographic divisions (Figure 4.33) the annual average precipitation ranges can be associated with each division. For example the Atlantic Plain and Interior Highlands correspond to the precipitation ranges of 41-70 inches of average annual rainfall.

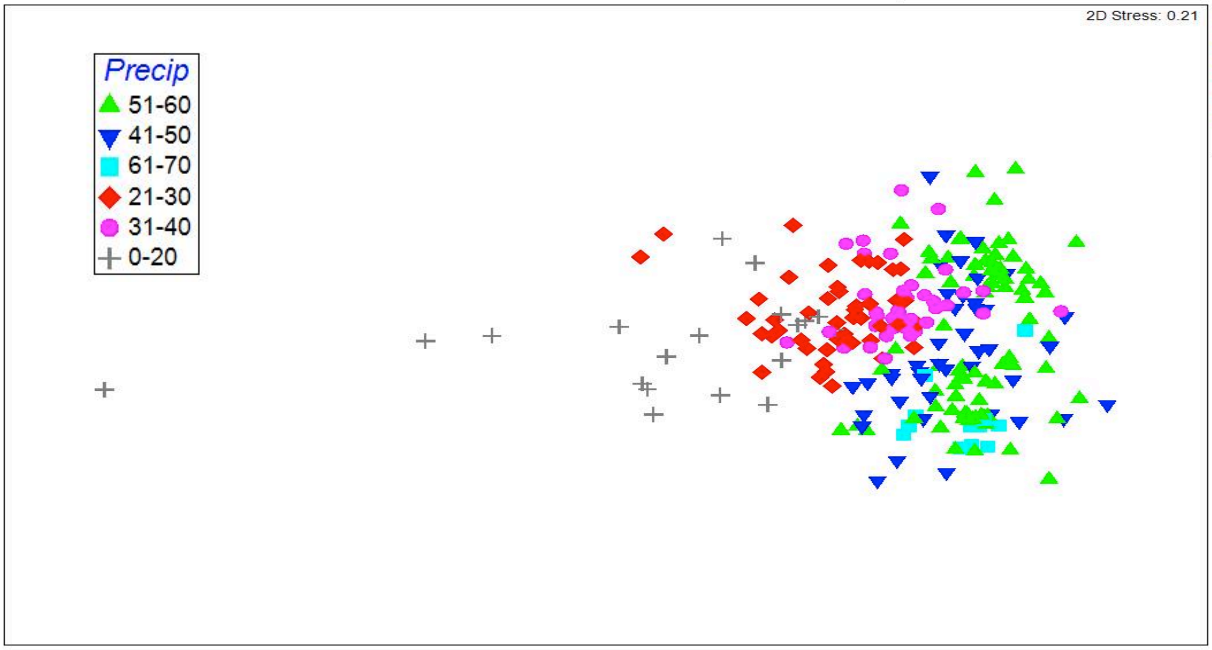


Figure 4.32: NMDS plot of Average Precipitation in inches from locations with 10+ species. Groupings appear to be a wet region of 41-70 inches, moderate precipitation region 40-21 inches and an arid region of 20 or less inches of rain on a eastern to western gradation (ANOSIM results: Global R = 0.234, p=0.001, 999 permutations).

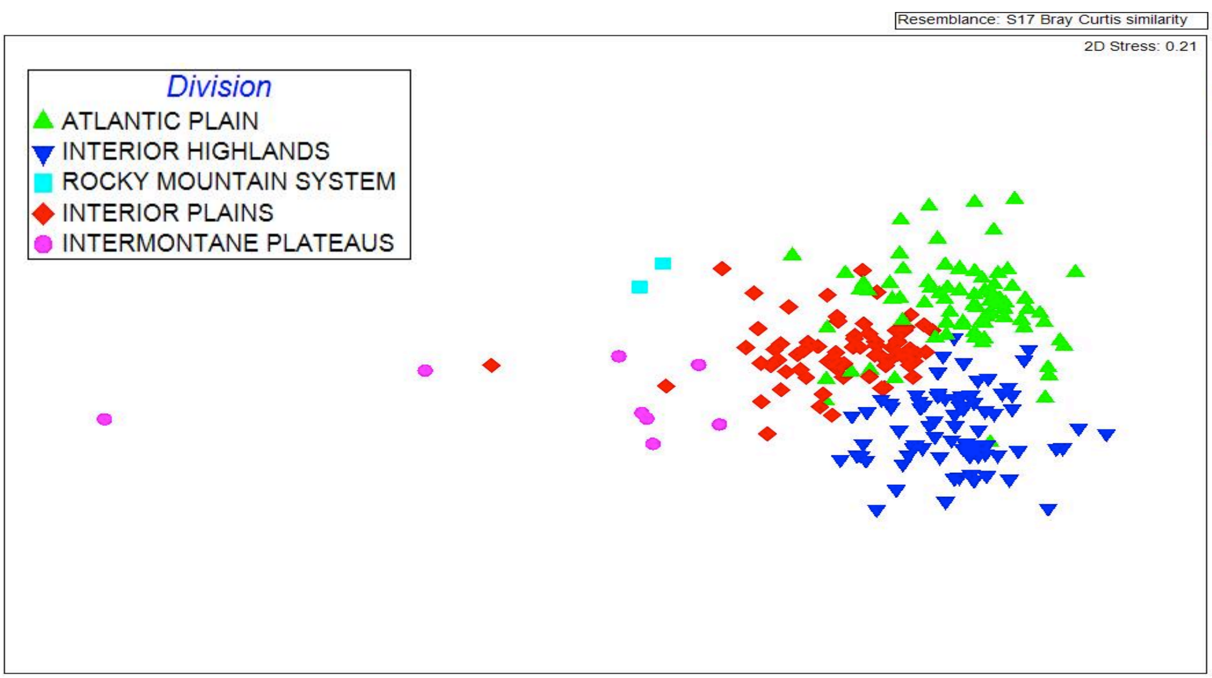


Figure 4.33: NMDS plot of physiographic division sites with 10+ species. In comparison to Average Annual Precipitation, areas with higher rainfall were associated with Interior Highlands and the Atlantic Plain, while more arid conditions were within the Intermontane Plateaus (ANOSIM results: Global R = 0.519, p=0.001, 999 permutations).

4.10.3 Ho_2. Caddisfly Communities will not Differ within the South-Central United States based on Ecoregion or Physiographic Region.

For both ecoregion and physiographic region scale and resolution become an important issue. EPA Ecoregions are broken into 4 levels with Level I being the coarsest and Level IV the most refined. Preliminary analyses suggest the fine scale of Level III and IV produces too many individual variables (sub-ecoregions) to decipher clear community groupings across such a large geographic scale. USGS Physiographic Regions contain 3 levels increasing in refinement from division > province > section. Similar to Ecoregion Level III and IV, physiographic sections provide too fine a resolution to use across a large geographic area.

Global R for Ecoregion Level I was maximized (R=0.350, p=0.00001, 99,999 permutations) at 8+ species and decreased as the minimum number of species increased (Table 4.20). Ecoregion Level II analyses with a minimum of 8+ species had a Global R = 0.514 (p=0.00001 for 99,999 permutations)(Table 4.20). As the minimum number of species increased so did the Global R statistic. Even though 8+ species produced a significant R-value, the NMDS plot of community structure utilizing 10+ species produced more clearly defined groupings (Figure 4.34). NMDS 10+ species plot has 3 large community groups based on species structure: Southeastern USA Plains, Ozark/Ouachita-Appalachian Forests, and South Central Semiarid Prairies. ANOSIM analyses of 10+ more species has a Global R = 0.571 with p=0.00001 at 99,999 permutations (Table 4.20)(Figure 4.35) and 0 permutations that are greater than the Global R.

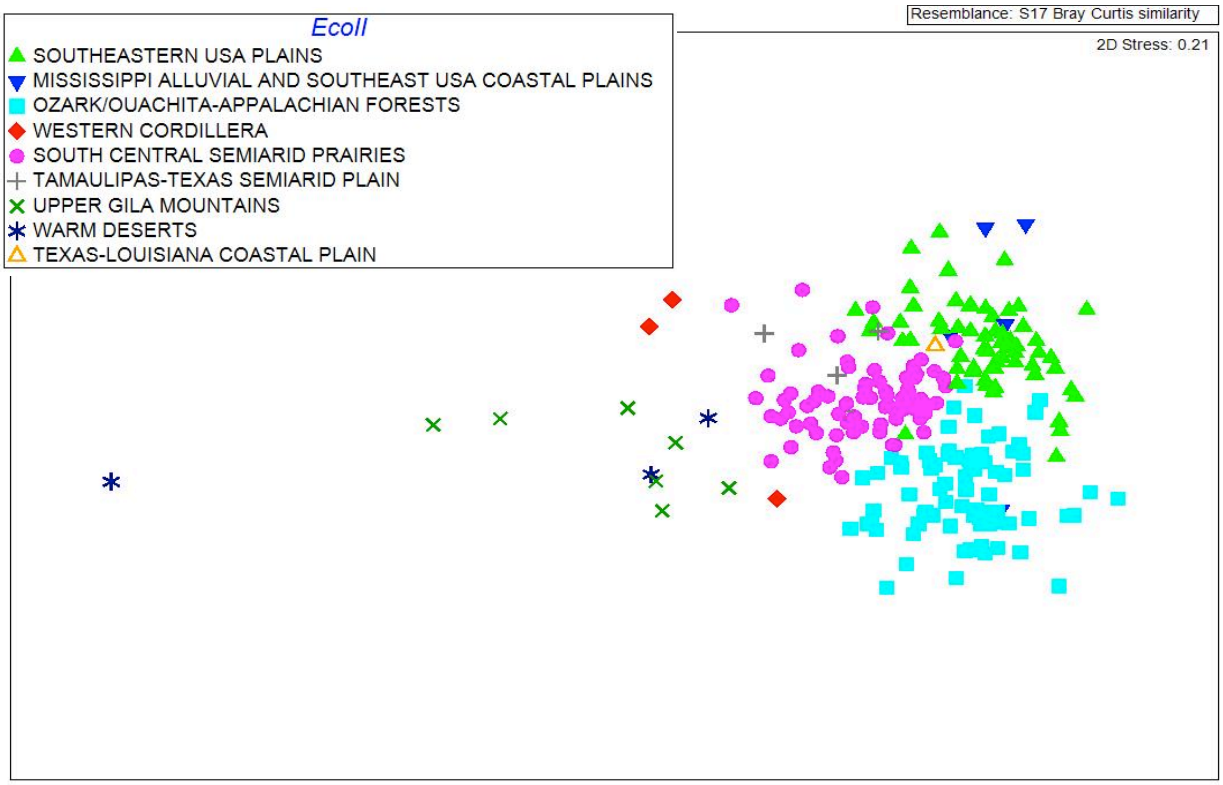


Figure 4.34: NMDS plot of EcoRegions Level II with sites containing 10+ species (239 total individual sites). Three large community groupings are evident based on species present: Southweastern USA Plains, Ozark/Ouchatia-Appalachian Forests, and South Central Semiarid Plain.

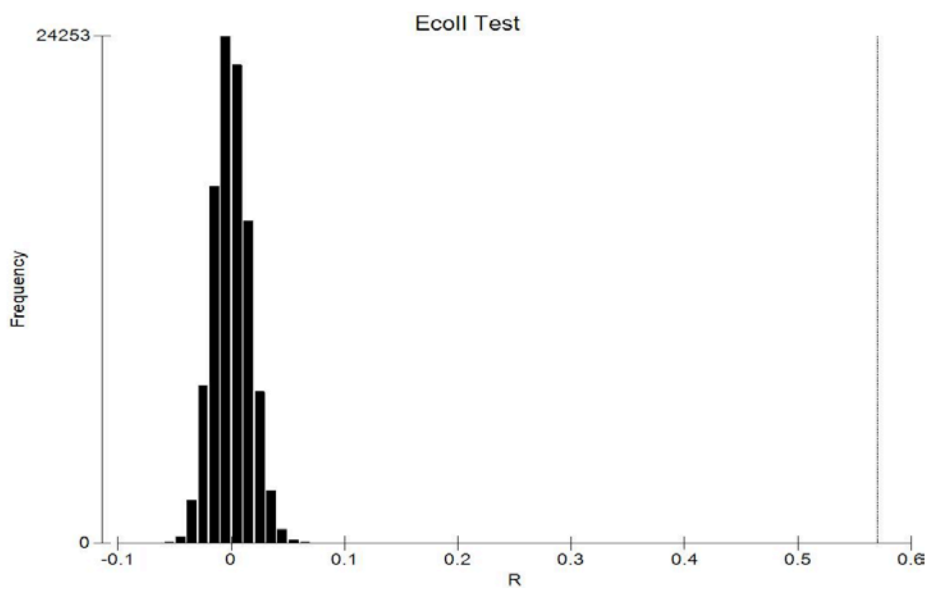


Figure 4.35: ANOSIM output for EcoRegion Level II for sites with 10 or more species (Global R statistic = 0.571, p= 0.00001, 99,999 permutations with 0 being greater than or equal to Global R).

Physiographic regions were analyzed at the level of division, province and section; both divisions and sections had higher Global R statistics across all minimum number of species compared to provinces (Table 4.20). Figure 4.33 shows the community stucture of 10+ species using physiographic divisions with the Interior Highlands, Atlantic Plain and Intermontane Plains being the predominate divisions based upon species community structure. However, if physiographic provinces (Figure 4.36) are used a finer division of community structure can be distinguished - similar to Level II Ecoregion (Figure 4.34). A comparison of NMDS plots between divisions and provinces reveals a high level of similarity; the Atlantic Plain Division is contiguous with the Coastal Plain Province, the Interior Plain Division is subdivided into the Central Lowlands and Great Plain Provinces, and the Interior Highland Division is divided into the Ouachita and Ozark Plateau Provinces (Figure 4.36). ANOSIM analysis of physiographic provinces has a Global R = 0.498, p=0.00001 at 99,999 permutations (Table 4.20)(Figure 4.37). As with Level III and Level IV Ecoregions, physiographic section is too fine a scale to obtain good resolution of commuity structure, so even though ANOSIM analyses have Global R values higher for divisions and sections, the NMDS plot of provinces provides better resolution for community structure with a minimum of 10+ species.

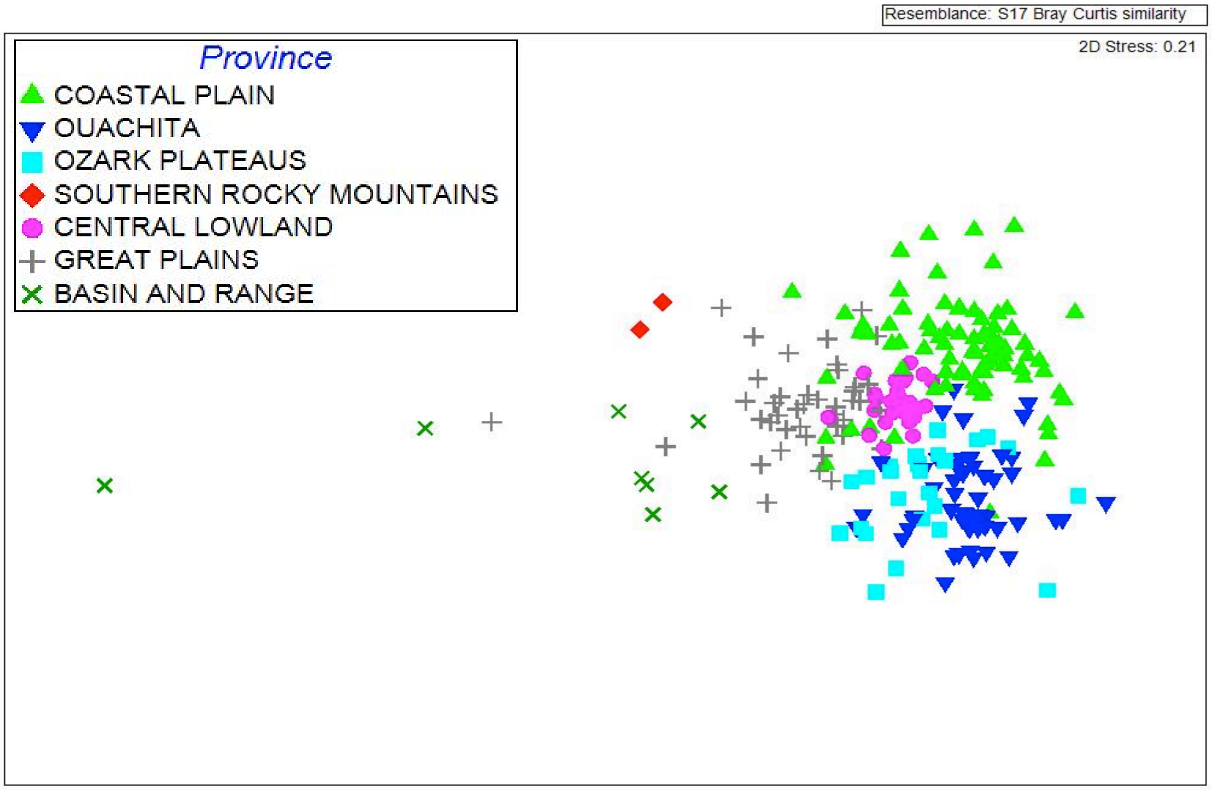


Figure 4.36: NMDS plot of physiographic province sites utilizing 10+ species (239 total individual sites). Five distinct communities are distinguished at this scale: Coastal Plain, Ouachita, Ozark Plateaus, Central Lowland, and Great Plains.

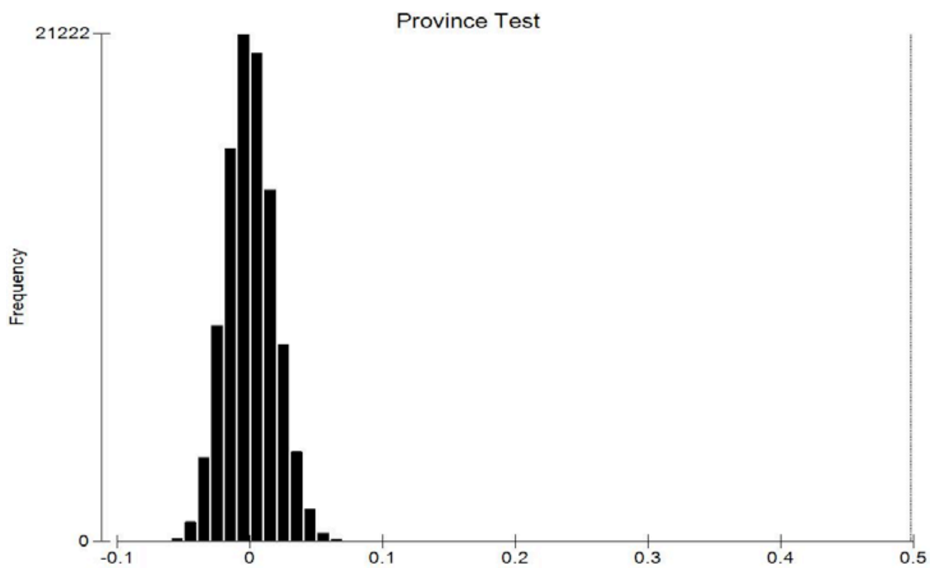


Figure 4.37: ANOSIM output for physiographic province for sites with 10 or more species (Global R statistic = 0.498, p= 0.00001, 99,999 permutations with 0 being greater than or equal to Global R).

4.10.4 Ho_3. Caddisfly Communities will not Differ by Hydrologic Unit Code 4 (HUC 4)

HUC 4 sub-watersheds were chosen over HUC 2 because the scale and resolution was more appropriate for the study region. As with the last two variables, hydrologic units can be broken into subsequently smaller units, however smaller HUC's made for too many variables for any meaningful analyses. HUC 4 ANOSIM analyses for 8+ species had a Global R value =0.553 (p=0.00001, 99,999 permutations) and for all other minimum number of species analyses the Global R was > 0.6 (Table 4.20, Figure 4.38). NMDS community structure plot contains 27 sub-watersheds and even with a minimum of 10+ species a few clusters are evident (Figure 4.38). One of the most obvious communities is within the Red-Washita sub-watershed (Gold Triangles). HUC 4 using 10+ species NMDS plot illustrates the mixing between sites and sub-watersheds the use of NMDS HUC 4 with 15+ species brings a clearer demarcation between sites due to the use of fewer sites (129)(Figure 4.39). Using this figure, a grouping of eastern sub-watersheds can be seen with the Neches, Sabine and Trinity River; Red-Washita forms a solid community with some minor mixing with other watersheds; and the Red-Sulphur, Upper White, Lower Red-Ouachita and Lower Arkansas. While HUC 4 ANOSIM analyses provided higher Global R statistics, NMDS diagrams were difficult to decipher due to the number of sub-watershed at the 10+ species criteria. Removal of species to 15+ species provided clearer groupings, it utilized 129 sites, or only 7% of the total number of sites.

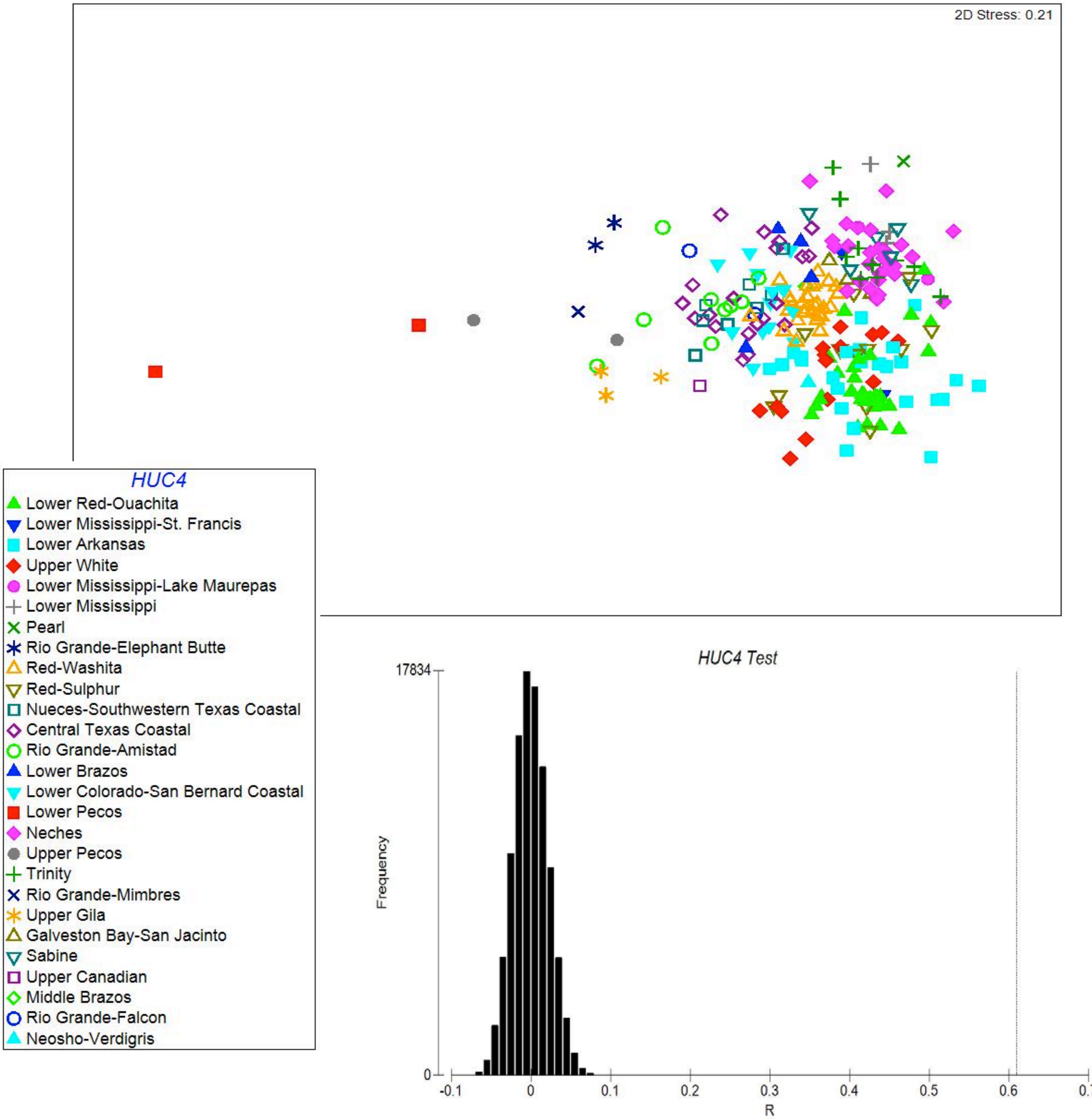


Figure 4.38: NMDS plot of HUC 4 watershed sites with 10+ species (239 sites). ANOSIM analysis for HUC 4 with 10+ species Global R statistic = 0.61, p=0.0001 with no permutations equal to or greater than Global R (99,999 runs).

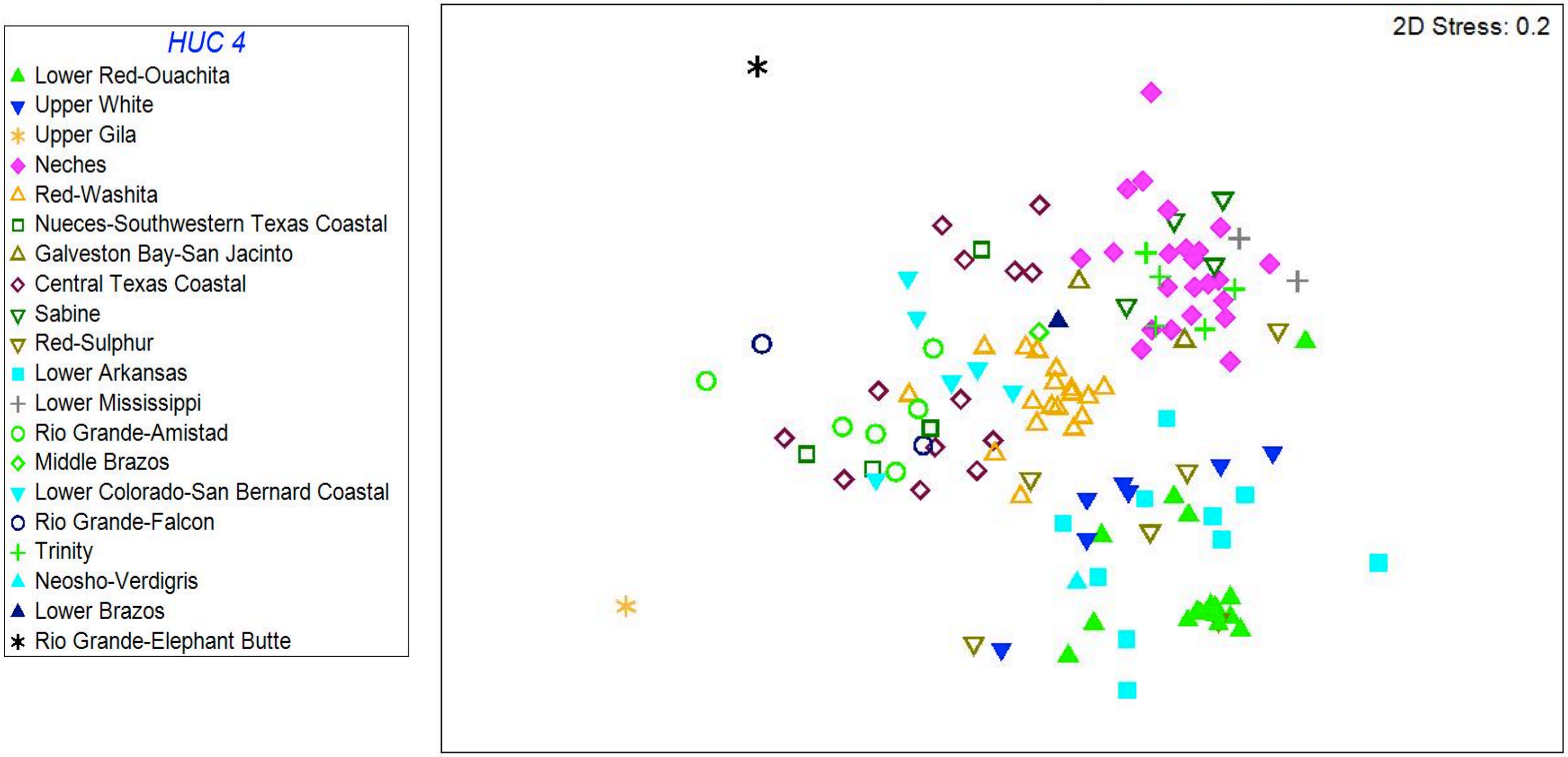


Figure 4.39: NMDS plot of HUC 4 sub-watersheds with 15+ species (129 sites). ANOSIM results Global R = 0.689, p=0.00001 at 99,999 permutations.

4.10.5 Ho_4: Sample Locations will not be Biased Towards Charismatic Locations (e.g. Physiographic Sections)

The variable physiographic sections was chosen for this analysis because: 1) it is the finest scale at which physiographic region was analyzed, 2) many endemic species reside within this finer scale, 3) this variable was the most statistically significant for all the minimum number of species analysis (Table 4.20). A total of 1,914 sample locations were broken into and analyzed by the 18 physiographic sections using Chi-square analysis (R Core Team 2014). Analysis using all 18 physiographic sections found that sampling location bias was highly statistically significant (X^2= 2113.2, df=17, p<0.00001), and was primarily driven by the variable West Gulf Coastal Plain that had 495 sampling locations. Removal of West Gulf Coastal Plain sampling locations (1,419 sampling locations) Chi-square analysis was still statistically significant (X^2= 776.19, df=16, p<0.00001).

4.10.6 Caddisfly Community Similarity

SIMPER analysis of physiographic provinces was run at with at 65% cut-off for species with low contributions. There are 7 individual provinces within the south-central United States and Table 4.21 lists the total number of sites, percent average similarity between sites for each province, and the species that contributes to percent average abundance by at least 70% (except for Great Plains, the species with the highest percent average abundance are given). Southern Rocky Mountain data was omitted because only 2 sample sites were included in the analysis and all the species had 100% average abundance because they were collected from all the sites, and all between group analyses with Southern Rocky Mountain province was removed. Appendix E has the full output of all individual group analyses as well as between group analyses; Tables 4.21 and 4.22 document the data discussed below.

SIMPER analyses for sites within a Physiographic province provided the percent average similarity of species composition between sites for each province. Most of the provinces had percent average similarities ranging from 20.54-28.58, except for sites in the Central Lowlands province, which had a percent average similarity between sites of 45.97. Even though this province had 30 sample sites, the species list was comprised of only 10 species and percent average abundance ranged from *Oecetis inconspicua* (Leptoceridae) in 97% of the samples to *Hydropsyche bidens* (Hydropsychidae) and *O. cinerascens* (Leptoceridae) both with average abundances of 63% Table 4.20 and Appendix E. Eight of the species reported from this province had an average percent abundance in sample sites of 70% or higher (Table 4.21).

Coastal Plain province had a 20.54% average similarity between the 77 sites located within this province, with *Oecetis inconspicua* (Leptoceridae) having a 70% average abundance. The remaining 17 species ranged from 49-26% average abundances (Table 4.21). The Ouachita province consisted of 55 sites and 11 species; the average similarity between sites was 25.79%. Two species, *Polycentropus centralis* (Polycentropodidae) and *Chimarra obscura* (Philopotamidae) had average abundances of 76% and 73%, respectively (Table 4.21). Additional species ranged from 62-33% average abundances (Appendix E). Ozark Plateaus were comprised of 25 sites and 15 species with an average similarity of 21.04%. Only one species, *Chimarra obscura* had an average abundance over 70% (72%), the remaining species ranged from 48%-32% (Table 4.21, Appendix E). The Great Plains province was represented by 42 sites with

16 species and an average similarity of 23.72% between sites. This province had no species with a 70% or greater average abundance, and the highest average abundance was 52% for both *Chimarra obscura* and *Cheumatopsyche comis* (Hydropsychidae). Other species average abundance from the Great Plains ranged from 50-31% (Table 4.22, Appendix E). Basin and Range province had an average similarity of 28.58% from 8 sites and 6 species. Two species of Hydroptilidae had average abundances of 88%, *Hydroptila arca* and *Ochrotrichia dactylophora,* the remaining species had average abundances of 63-50% (Table 4.21, Appendix E). Caddisfly species which represented the highest average abundance in each province were representatives of only 5 families: Hydropsychidae (4 species), Leptoceridae (4 species), Polycentropodidae (1 species), Philopotamidae (1 species) and Hydroptilidae (2 species). Three genera were represented by more than one species *Cheumatopsyche* (3 speices), *Oecetis* (2 species) and *Triaenodes* (2 species).

Table 4.21: SIMPER species similarity for physiographic provinces with 10+ species at each site (Low contribution analysis cut off 65%). The number of samples by province, average species similarity between sites for each province, species that were of the highest percent average abundance by province (provided species with a minimum of 70% abundance or higher, except for Great Plains) are provided in this table, raw analyses data can be found in Appendix E.

Province	# Sites	# Sp.	% Avg Sim	Species	% Avg Abun
Coastal Plain	77	18	20.54	*Oecetis inconspicua*	70
Ouachita	55	11	25.79	*Polycentropus centralis*	76
				Chimarra obscura	73
Ozark Plateaus	25	15	21.04	*Chimarra obscura*	72
S Rocky Mtns	2	7	40.82	-NA-	

(table continues)

Province	# Sites	# Sp.	% Avg Sim	Species	% Avg Abun
Central Lowland	30	10	45.97	*Oecetis inconspicua*	97
				Triaenodes tardus	80
				Chimarra obscura	80
				Cheumatopsyche campyla	77
				Cheumatopsyche analis	77
				Triaenodes injustus	70
				Oecetis avara	70
				Potamyia flava	70
Great Plains	42	16	23.72	*Chimarra obscura*	52
				Cheumatopsyche comis	52
Basin & Range	8	6	28.58	*Hydroptila artica*	88
				Ochrotrichia dactylophora	88

Table 4.22: Average dissimilarity between species communities compared between physiographic provinces. Southern Rocky Mountain province was omitted due to small number of samples (SIMPER, 65% cut-off for low contributions).

Province A	Province B	% Dissimilarity	# Species	Common Sp
Coastal Plain	Ouachita	90.43	61	50
Coastal Plain	Ozark Plateaus	89.89	65	49
Ouachita	Ozark Plateaus	81.01	47	45
Coastal Plain	Central Lowland	80.73	45	40
Ouachita	Central Lowland	84.69	41	26
Ozark Plateaus	Central Lowland	81.33	43	31
Coastal Plain	Great Plains	90.09	62	47
Ouachita	Great Plains	91.94	58	21
Ozark Plateaus	Great Plains	90.22	61	21
Central Lowland	Great Plains	80.24	39	31
Coastal Plain	Basin and Range	99.09	60	10

(table continues)

Province A	Province B	% Dissimilarity	# Species	Common Sp
Ouachita	Basin and Range	99.14	49	3
Ozark Plateaus	Basin and Range	97.28	53	7
Central Lowland	Basin and Range	96.69	37	6
Great Plains	Basin and Range	93.34	46	22

Dissimilarity analyses between groups (Province A vs. Province B) are provided in Table 4.22, percent dissimilarity ranged from 80.24-99.14 and the number of species ranged from 37-65. Between group analyses does not use the cut-off contribution, so all species are included even if their average abundance contribution is 0. This analysis bolsters the groupings that can be seen in the NMDS plot for physiographic provinces (Figure 4.36). Of the 15 group wise comparisons, 4 pairings are graphically clustered to giving the impression that they are more similar than they are in an *n*-dimensional NMDS plot.

Coastal Plain vs. Central Lowland: a total of 45 species were reported from these two provinces, with 40 being in common between the two provinces (Table 4.22, Appendix E). The dissimilarity between these provinces is 80.73% (or species similarity of 19.27%), and *Oecetis inconspicua* was reported at the species with the highest average abundance in both of these provinces. Of the 45 species collected between these two provinces, 5 were present in the Coastal Plains that were not reported from the Central Lowlands while all species from the Central Lowlands were collected in Coastal Plain sampling. Five species were given a value of 0 average abundance in the SIMPER group dissimilarity analysis for Central Lowlands: *Macrostemum carolina* (Hydropsychidae), *Hydropsychidae mississippiensis* (Hydropsychidae), *Triaenodes* *ignitus* (Leptoceridae), *Phylocentropus placidus* (Dipseudopsidae), and *Chimarra parasocia* (Philopotamidae) (Figure 4.40). However, ne record of *T. ignitus* was reported for the Central Lowlands but the remaining locations for this species are mainly from the southeastern portion of Texas near the border between Texas and Louisiana (Figure 4.40).

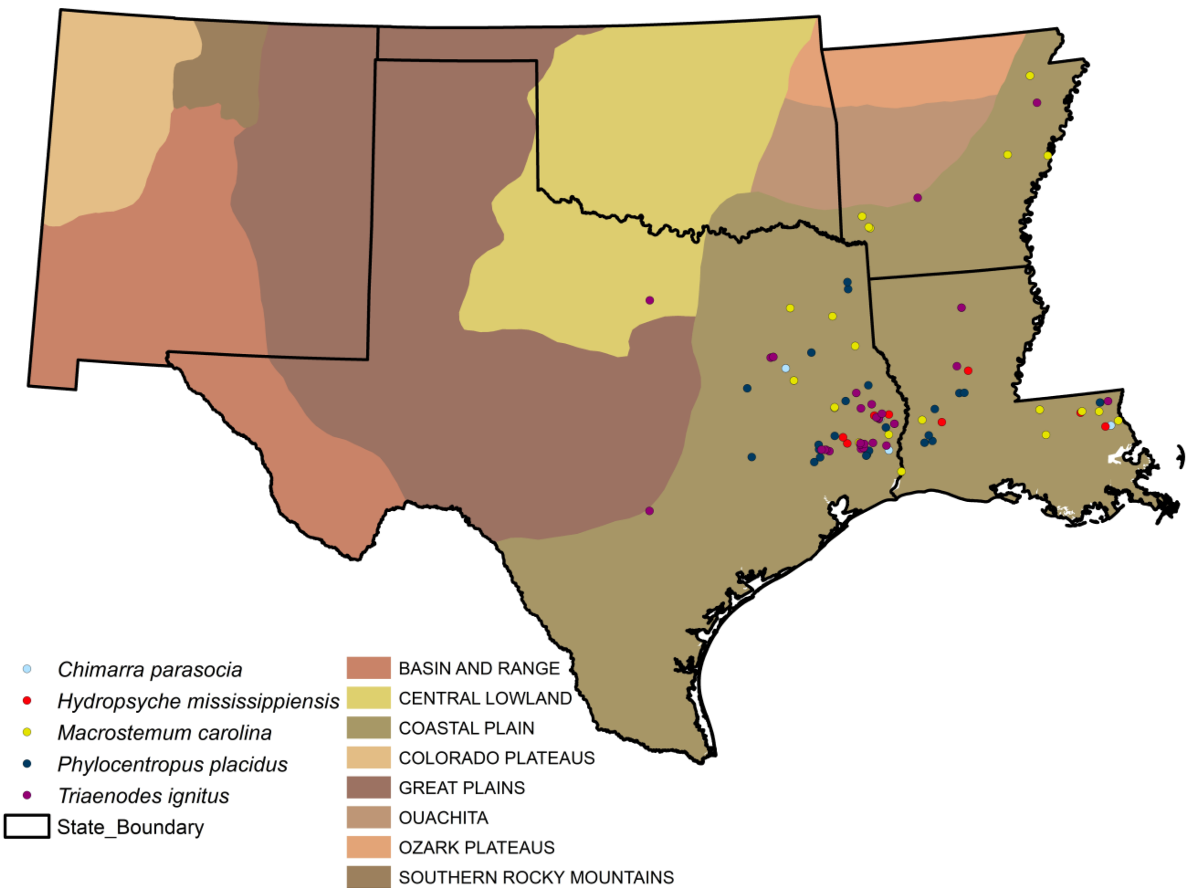


Figure 4.40: Coastal Plain vs. Central Lowland SIMPER dissimilarity analysis species that were not found in both physiographic provinces. Five species are plotted that were given an average abundance of 0 in the SIMPER dissimilarity analysis. All were located within the Coastal Plain except for one record of *Triaenodes ignitus* (Leptoceridae) that was reported from the Central Lowlands.

Ouachita vs. Ozark Plateaus: 47 species were documented from these provinces and a species dissimilarity of 81.01% or 18.9% of the species were similar between the Ouachita and Ozark Plateaus. Of the 47 species used in this analysis, 45 were common between the provinces (Table 4.22). Two species, from the Ouachita province were not reported in the Ozark Platueaus and given an average abundance of 0 via the SIMPER dissimilarity analysis: *Cheumatopsyche robisoni* (Hydropsychidae) and *Agrypnia vestita* (Hydrobiosidae) but all species collected from the Ozark Plateaus were documented in the Ouachita province samples (Figure 4.41). The Ozark Plateaus are north of the Ouachita province but due to their proximity to each other in western Arkansas and eastern Oklahoma species ranges could fluctuate between provinces in areas where suitable habitat is available. These provinces both have *Chimarra obscura* as one of or the most average abundant species within the province with 73% abundance in Ouachita province and 72% in Ozark Plateaus. The most average abundant species in the Ouachita province was *Polycentropus centralis* (76%), this species is found within the Ozark Plateaus but only at a 40% average abundance (Table 4.22, Appendix E).

Central Lowlands vs. Great Plains: the Great Plains province is the second largest province for the south-central United States; occupying the central, western and panhandle portions of Texas; the panhandle of Oklahoma and the eastern border of New Mexico. A total of 39 species were documented for between these provinces and the species dissimilarity was 80.24% the lowest dissimilarity between all groupings (Table 4.22). Eight species had average abundances of 0 with the SIMPER dissimilarity analysis. *Hydropsyche scalaris* (Hydropsychidae) was the only species to have an average abundance of 0 for the Great Plains. Seven species were given an average abundance of 0 for the Central Lowlands. However, three species are present in the Central Lowlands that have an average abundance of 0: *Chimarra angustipennis* (Polycentropodidae), *Cheumatopsyche comis* (Hydropsychidae), and *Nectopsyche* *gracilis* (Leptoceridae)(Figure 4.42). *Chimarra obscura* and *Cheumatopsyche comis* both had an average abundance of 52% from Great Plains sites, however these species in the Central Lowlands had 80% and 0% average abundance, respectively (Appendix E). *Oecetis inconspicua* was 97% average abundance in Central Lowland sites but only a 45% average abundance in Great Plains sites. Many species in this analysis have similar average abundances between provinces (e.g. *Helicopsyche borealis* 47% and 43%, respectively) or in one province the species has a high average abundance and in the other province the species average abundance is around half (e.g. *Hydropsyche simulans* 53% and 24%, respectively).

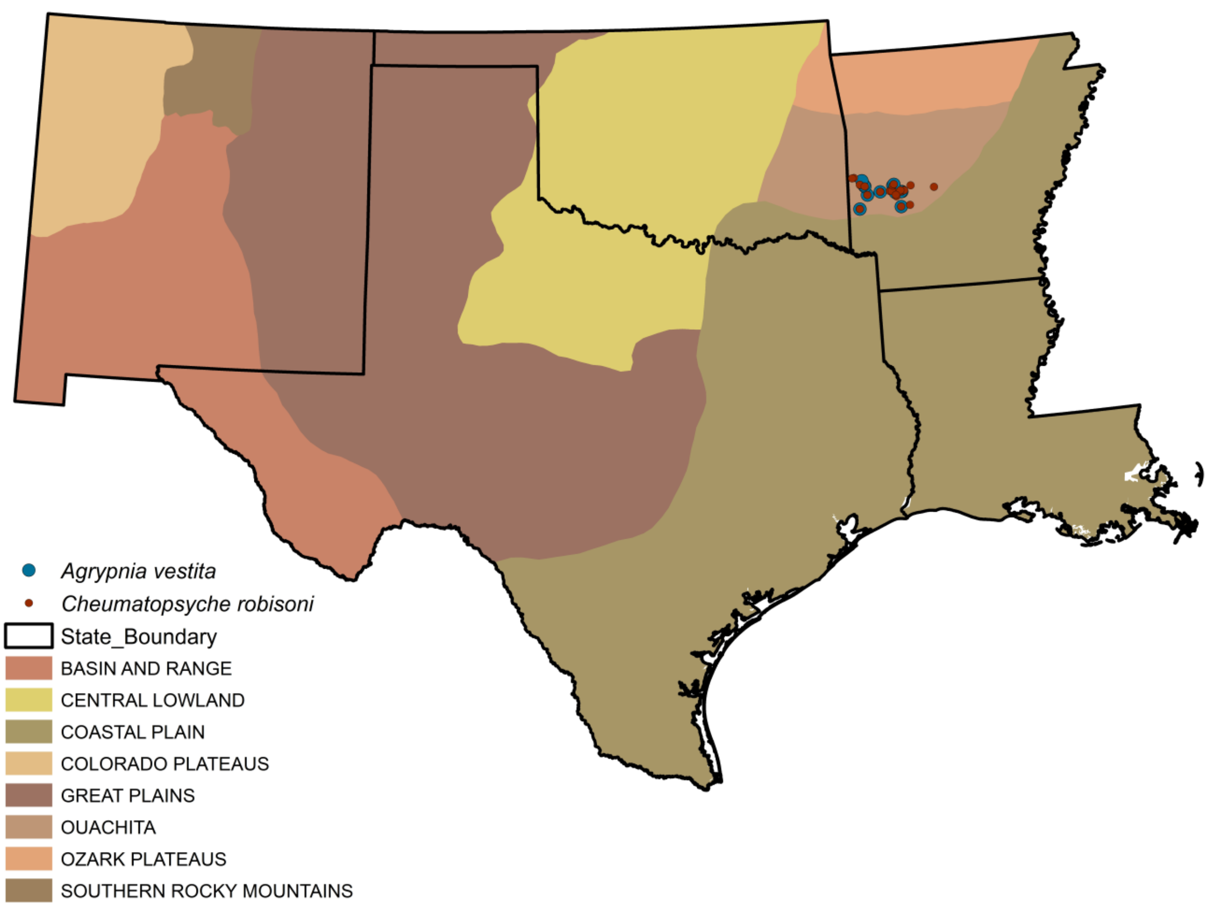


Figure 4.41: Ouachita vs. Ozark Plateaus province SIMPER dissimilarity species with average abundances of 0; two species *Cheumatopsyche robisoni* and *Agrypnia vestita* were only reported from the Ouachita province while all species collected from the Ozark Plateaus were collected from the Ouachita province.

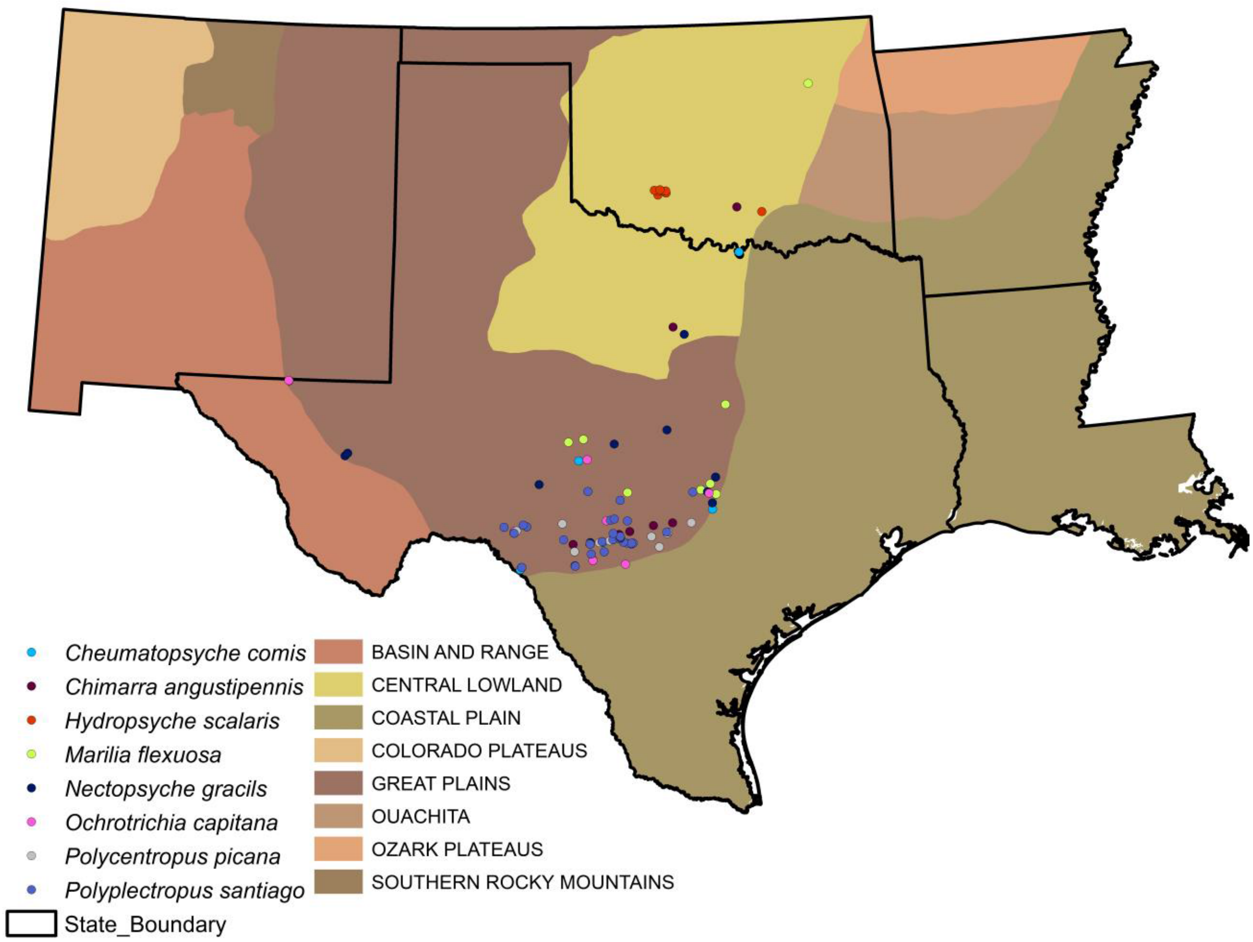


Figure 4.42: Central Lowland vs. Great Plains province SIMPER dissimilarity species with average abundances of 0; eight species had average abundances of 0, and using the output from the dissimilarity analysis 1 species had an average abundance of 0 for the Great Plains, while 7 had an average abundance of 0 for the Central Lowlands. Three species with an average abundance of 0 for the Central Lowlands have records for this physiographic province: *Cheumatopsyche comis*, *Chimarra angustipennis*, and *Nectopsyche gracilis*.

Coastal Plains vs. Great Plains: these provinces converge along the Balcones Fault line in central Texas (Appendix D). The Coastal Plains contains the Blackland Prairie Ecoregion and streams in this area are known for their muddy bottoms, while the to the west of the Blacones Fault line lies the central part of Texas commonly referred to as the Texas Hill Country and streams in this region are often characterized with limestone bedrock substrate. Sixty-two species were documented for these provinces with only 47 being found in both provinces giving this group comparison 90.09% dissimilarity (Table 4.22). Three species had the highest average abundances between these two provinces: *Oecetis inconspicua* (70% vs. 45%), *Chimarra obscura* (31% vs. 52%), and *Cheumatopsyche comis* (1% vs. 52%) for Costal Plains vs. Great Plains (Appendix E). The 15 species that were not collected in both provinces can be divided into 4 not collected during Coastal Plain samplings and 11 not in Great Plains samples.

It is worth mentioning that while the Basin and Range province was a distinct group within the NMDS plot (Figure 4.36), and dissimilarity group comparisons between the Basin and Range province with the other 7 provinces ranged from 93.34-99.14% (Table 4.22) there are few comparisons worth pointing out. Due to geographical location of the Basin and Range province to the Ouachita province their grouping had the highest dissimilarity, 99.14% and these provinces had only 3 species in common, or 6% shared species, out of 49 listed for these provinces: *Helicopsyche borealis* (Helicopsychidae), *Hydroptila hamata* (Hydroptilidae), and *Oecetis avara* (Leptoceridae) (Appendix E). The province that had the lowest dissimilarity in a grouping with Basin and Range was Great Plains, 93.34%. Of the 46 species reported from samples in these physiographic provinces nearly 48% (22) are in common between these provinces.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 Natural History Collections: Their Use and Limitations

There are an estimated 2.5-3 billion biological specimens housed in the world's museums of natural history and herbaria (Pyke and Ehrlich 2010). In recent years there has been a push to digitize museum records to make them more accessible for researchers through online portals such as the Global Biodiversity Information Facility (GBIF) (Boakes et al. 2010, Beck et al. 2014, GBIF 2017a). However, a few problems arise with these types of records: 1) sampling bias, 2) expert identification, and 3) uneven sampling (Boakes et al. 2010, Yang et al. 2013, Ball-Damerow et al. 2015).

Sampling biases can be attributed to factors such as targeting of charismatic species, temporal trends in sampling by only sampling during certain months or years, and spatial bias of sampling charismatic locations or easily accessible locations (e.g. stream road crossings). Even with these biases museum collections house the best historical record available over a broad taxonomic and geographical span, and have a heavy concentration of useful specimens (Boakes et al. 2010, Yang et al. 2013). Caddisfly records for the south-central United States at a temporal scale illustrate a typical "boom and bust" cycle in collection efforts. For example spikes in caddisfly sampling in this region occurred in the 1930s, 1960s, and again from the 1980s-2000s. Ball-Damerow et al. (2015) saw similar temporal trends with California dragonfly and damselfly database records for a similar time period.

The majority of the NHC records gathered for this data set were either housed in a collection that is actively curated by an expert in Trichoptera taxonomy (e.g. University of Minnesota – Dr. Ralph Holzenthal), or had been visited or loaned to an expert for verification (e.g. University of Arkansas collection verified by Dr. John Morse). However, one of the largest data sets received for this study was from the Illinois Natural History Survey (INHS). Data submitted provided no associated verification information for records. While H.H. Ross was at the INHS for over 40 years, one can only assume that he verified records acquired under his tenure. With subsequent records having no details of species verification the issue of potential inaccuracies exists concerning both the species identified and associated distributions (Appendix C). Efforts were made to ascertain if INHS records were verified, no response was received to confirm whether expert taxonomists verified records.

Uneven sampling efforts were encountered throughout many of the NHC records. While museum data contains a wealth of information concerning collection locality, date collected, species identification etc. they generally do not come with information concerning sampling type or effort. Species richness, especially in arthropods, can vary across locations as a result of environmental factors and / or sample timing. Reporting information on the duration and effort of sampling would increase the users ability to determine if variation may be the result of sampling effort or some other environmental factor. This would be especially important in large surveys where collectors were traveling long distances and reported low species counts for some locations and not others.

In an effort to establish baseline data for caddisfly species and distributions within the south-central United States 36 NHCs were contacted or searched for records. Eighteen NHCs provided records either digitally or via in-person scribing. Over 12,000 records were obtained, with more than 10,000 providing useful information documenting species, and geographic distributions that spanned over a century. Three collections provided 65% of the total records: David E. Ruiter, Illinois Natural History Survey, and S.R. Moulton Collection. Records that were not utilized lacked either useful geographical location data (e.g. state only) or species identification was done at a higher taxonomic scale other than species. However, even with the removal of these records, 82% of records were retained. Boakes et al. (2010) had a similar record retention rate of Galliformes records, 86%, after purging insufficient records from the more than 170,000 records they assembled from 121 museums.

Limitations for this dataset arose in a few areas: reported abundances, collection date, and species identification/verification. Abundance data was not given for all or some records from a few NHC requiring that all records be given the same treatment statistically (presence/absence). Collection dates for a limited number of NHC's were only provided for the year, therefore providing emergence data for each species could not be achieved. In the instance of questionable species identifications those records were removed due to the lack of information concerning the person(s) who made the identification.

5.2 Geographic Variables Influencing Caddisfly Biogeographic Distributions in the South-Central United States

Several geographic variables were assessed to establish which factor would best explain caddisfly community structure and biogeographic distributions within the south-central United States. HUC 4 sub-watershed was the most statistically significant geographical factor evaluated across all caddisfly species treatment values, and is seemingly the most ecologically relevant variable to determine caddisfly distributions. However, this variable is not equally represented within this data set. A total of 44 HUC 4 watersheds are within the study region, but only 27 contained caddisfly communities with 10+ species for sampled locations. The number of HUC 4's sampled decreased as the minimum number of species used increased. In several instances a HUC 4 was represented by only one location that met the minimum species requirement.

Similar research conducted in Minnesota and the Interior Highlands of Arkansas indicated that caddisfly communities could be delineated through sampling sub-watersheds. Houghton (2004) and Moulton and Stewart (1996) utilized sub-watersheds as a sampling unit to determine caddisfly distributions for their respective studies. Houghton used HUC 10 sub-watersheds as the most appropriate geographical factor to delineate caddisfly bioregions in Minnesota. This author was able to group the sub-watersheds into 5 general geographical regions based on a variety of *in situ* measured environmental factors and caddisfly community composition. Moulton and Stewart's Interior Highland study showed that species community structure was influenced by watershed region and for their analysis both HUC 8 and HUC 10's sub-watersheds were utilized. They were able to discern two distinct groupings, the Ouachita and the Ozark watersheds, based on these sub-watersheds. They found that the environmental parameters of latitude, geology, and high-volume springs were statistically significant in assigning sub-watersheds to one of the two larger watershed groups from their analyses.

With additional equal effort sampling of all HUC 4 sub-watersheds within the study area this would likely be the most appropriate geographic variable to assess the biogeographic distribution of caddisflies within the south-central United States. However, due to the uneven sampling across sub-watersheds it was determined that this variable should not be utilized to represent caddisfly community structure in this study.

Hynes (1975) stated, “the valley rules the stream”. Factors such as geology, topography, climate, and soils influence water chemistry, sedimentation, slope, vegetation, temperature, and other abiotic variables. These factors clearly influence stream ecological condition and are often described using the ecoregion approach (Snelder and Biggs 2002). Omernik defined ecoregions as areas based up the climate, mineral availability (soils and geology), vegetation, and physiography (1987). However, ecoregion classification is not accomplished according to any consistent model of ecological processes or criteria. Specific ecoregions often emphasize unrelated classification factors (e.g. topography in mountain ecoregions and soil or vegetation in valley ecoregions) and factors often vary within a classification level to make use of whichever characteristic best distinguishes each ecoregion (Snelder and Biggs 2002). Level II Ecoregion was statistically significant across all minimum number of caddisfly species treatments. However, the use of ecoregion as a geographical factor for this study would mean utilizing a variety of factors at different scales following the definition provided above and therefore this variable was not selected as the best representation for evaluating caddisfly biogeographic distributions.

The last geographical variable tested for caddisfly biogeographic community structure was physiographic regions, which are compromised of 3 nested groups arranged in a hierarchical scale structure. Physiographic divisions of the conterminous

United States are defined by the USGS (2015a) as distinctive areas with common topography, rock structure, and geologic and geomorphic history. They are further divided into provinces and sections that are associated with other ecological factors (e.g. vegetation). Since physiographic regions are defined by geology, and geology directly influences water chemistry this variable was used as a surrogate for HUC 4 watersheds. Scale was considered when determining which physiographic variable to use, as well as sampling coverage.

Caddisfly samples were mapped against the physiographic regions to determine if all regions were represented by caddisfly community samples in 1) the total data set and 2) the 10+ ANOSIM analysis. Physiographic division contains 5 variables, which were all represented in both the total dataset and the 10+ ANOSIM analysis. physiographic provinces are represented by 8 variables, all of which were included in the total data set, but the Colorado Plateau Province had no samples that met the minimum sample requirement for the 10+ ANOSIM analysis. Physiographic Sections contains 20 variables, all of which were represented in the total data set except for the Plains Border Section. However, under the 10+ ANOSIM analysis the High Plains, Datil, and Navajo Sections contain no sampling locations. Additionally, the Raton Section contains only 1 sampling location under the 10+ ANOSIM analysis. Other western Physiographic Sections are represented by small (5 or less) numbers of sites under the 10+ ANOSIM analysis. The lack of Section representation under the 10+ ANOSIM analysis, and therefore a lack of proper scale representation, makes Physiographic Sections an insufficient geographical variable to represent the biogeographic distribution of caddisflies in this data set. Although all physiographic divisions were represented in both the full data set and the 10+ ANOSIM analysis, Physiographic provinces divided several of the larger divisions into smaller sections so they could be analyzed separately in order to differentiate caddisfly community structure in geographical areas that are adjacent to each other (e.g. Interior Highlands subdivides into the Ouachita and Ozark Plateaus) and provide finer resolution and therefore more appropriate scale.

5.3 Caddisfly Biogeography in the South-Central United States

5.3.1 Evolutionary Distributions

The first fossil caddisflies are documented from the early Jurassic period (200 mya), but Wiggins (2004) places their origins within the Triassic period (250 mya). The formation of large landmasses culminated in the formation of Pangaea ~150 mya. This was a fundamental event in the ability of earth's biota to move freely without the hindrances of ocean barriers. The breaking of Pangaea into the smaller continents of Laurasia (northern) and Gondwana (southern) facilitated the movement of the earth's flora and fauna to separate hemispheres (Wiggins 2004).

Diversification of caddisfly suborders illustrates how the separation of Pangaea and the subsequent formation into northern and southern hemisphere continents allows for families to be distributed across the equator through vicariance. For the suborders of Spicipalpia and Annulipalpia all of the extant families are distributed across the equator except for Rhyacophilidae. Extant families of the suborder Integripalpia are mostly relegated to either northern or southern hemisphere distributions and are placed into two infraorders Brevientoria (southern) and Plenitentoria (northern). Within these two infraorders there are families from each that span the equator, as well as families that span across continents within their respective hemispheres (Wiggins 2004).

5.3.2 Recent Geographic Events

The Laramide Revolution was an event during the Oligocene-Miocene, which was a mountain building period in western North America. This event occurred in pulses and would become what is now the large mountain ranges reaching from Canada to Mexico (English and Johnson 2004). Temperatures at higher latitudes cooled during this time period through the early Pliocene fragmenting deciduous forests and isolating caddisfly species in North America (Ross 1967). The Bering Bridge further encouraged trans continental dispersal of caddisflies between Europe and North America during the Pliocene-Pleistocene. Cooling northern temperatures moved some species southward into central North America (Ross 1967). Areas like the Interior Highlands were not affected physically by the Pliocene-Pleistocene glaciation but areas of warming and cooling existed. Due to the limited affects of the glaciation this area had continual inhabitation by terrestrial and aquatic fauna throughout this period (Moulton and Stewart 1996).

Caddisfly dispersal between North and South America has allowed for diverse fauna of tropical lineages that evolved between these closely associated regions (Ross 1967). Ross (1967) refers to this phenomenon as a Circum-Caribbean evolution due to the connection and separation of these two continents allowing for high diversity and endemism of species. The Mexican Transition Zone, described by Halffter (1962, 1964,1974, 1976, 1987) is a complex area where Neotropical and Nearctic insect fauna overlap. The zone includes areas of the southwestern United States, Mexico, and Central America extending to the Nicaraguan lowlands. The biogeography of the Mexican Transition Zone is due to the geological events of the Cenozoic that created a variety of environments and ecological refuges (Halffter 1987).

5.3.3 Disjointed Species Range

While species ranges can be disjointed or expand due to influences of either geological or environmental vicariance (Platnick and Nelson 1978, Erwin 1981, Poulton and Stewart 1991). Some distributions may require other explanations. Other methods of dispersal could include direct species introduction, indirect human activity, aerial planktonic dispersal via air currents, or thorough the exploitation of similar environmental habitats across states (e.g. montane streams, cold springs). While a literature search could find no published literature directly attributing any trichopteran species dispersal to direct introduction it has been documented in other groups including invertebrates. This phenomenon has been especially well documented in island ecosystems. Brasher (2003) documented more than 50 introduced species including aquatic invertebrates in Hawaii. While some species were introduced intentionally because they were deemed beneficial, others were the product of unintentional human mediated movement. Aerial plankton dispersal in insects is a passive dispersal mechanism where adult insects are moved via high altitude wind currents. Studies on aerial plankton by Glick documented a variety of insects and arachnids at various altitudes, including Trichoptera at over 4,000 feet (1939). Johanson (2003) determined that various methods of vicariance could have contributed to the sister species of *Helicopsyche kingstona* and *H. villegasia* being dispersed between Jamaica and Mexico, respectively. However, if geological separation of these species was more recent ancestral dispersal could have been achieved through aerial plankton dispersal.

An example of an interesting disjointed distribution from the south-central United States is that of *Hydroptila potosina* (Hydroptilidae). This species is reported in published literature from Texas and Mexico, it has also been documented in Hawaii (Rasmussen and Morse 2016). Since the geological formation of Hawaii is more recent than that of Texas and Mexico (and these landmasses were never attached), this distribution could be explained through the activity of aerial plankton dispersal or possibly human mediated movement.

5.3.3.1 Neotropical Distribution Influence

Physiographic provinces along the southwestern border of the study area continue into Mexico, Central and South America. The occurrence of some Neotropical species found in the south-central United States in this study may represent the northern extremes of some Neotropical ranges. For example the genus *Austrotinodes* is documented from Mexico, Central and South American, and the Caribbean Islands (Flint 1973), but the only Nearctic representation of the genus (*Austrotinodes texensis*) is found within the Edwards Plateau of Texas. On the other hand some Nearctic species distributions extend southward into the Neotropics. For example Polycentropodidae, *Cyrnellus fraternus* and *Cernotina calcea* are found throughout North America into

Canada (Rasmussen and Morse 2016) but who range into Central and South America (Rasmussen and Morse 2016, Holzenthal and Calor 2017).

Neotropical caddisfly fauna comprise two groups, the Chilean and Brazilian (Holzenthal and Calor 2017), but were also described as the Patagonian and Neotropical groups by Moor and Ivanov (2008). The caddisfly fauna of the Brazilian group are found in southern Mexico, Central America, the Antilles, and parts of South America. This group is of importance to this study due to the overlap of Neotropical and Nearctic species within the southwestern United States (Holzenthal and Calor 2017).

Fifteen families of caddisflies documented to have distributions within the south-central United States in this study are also found in both the Neotropical and Nearctic regions. Utilizing Holzenthal and Calor's (2017) species list of Neotropical caddisflies a total of ~120 species are known to inhabit locations north of Mexico. Eighty-eight have distributions that include the south-central United States. The families: Hydroptilidae, Lepidostomatidae, Leptoceridae, Philopotamidae, and Polycentropodidae have nearly continuous Nearctic and Neotropical distributions. Species representing these families with distributions from Canada to Mexico include *Ochrotrichia tarsalis, Orthotrichia aegerfasciella, O. cristata, Lepidostoma griseum, Nectopsyche candida, N. pavida, Oecetis cinerascens, O. inconspicua, Triaenodes frontalis, C. obscura,* and *Cyrnellus fraternus* (Holzenthal and Calor 2017).

Texas and New Mexico were the primary locations for Neotropical species distributions within the south-central United States (69 and 48 species respectively). Of the 87 species representing Neotropical distributions, less than half (37) were documented from only one of the five states. Arkansas, Louisiana, and Oklahoma, with

25, 16, and 33 species respectively, had fewer numbers of species with Neotropical distributions. This pattern may reflect a greater similarity in climate and habitat conditions shared by states that are somewhat closer to the Neotropical zoogeographic region. Some regional “hotspots” for species with Neotropical distributions were found in the region. In particular the Edwards Plateau of Texas, known for its karst topography, limestone geology, and cold spring fed streams, is the most northern distribution of several species including: *Protoptila alexanderi, Atopsyche erigia, Hydropsyche delrio, Neotrichia caxima, Ochrotrichia felipe, Oxyethira ulmeri, Chimarra beameri, Polycentropus picana,* and *Polyplectropus misolja* (Holzenthal and Calor 2017).

The most speciose family with Neotropical distributions is Hydroptilidae. *Hydroptila*, *Oxyethira*, *Leucortichia*, and *Ochrotrichia* represent a majority of the “micro-caddisfly” genera with Neotropical affinities. Several of the Neotropical *Hydroptila* have extensive Nearctic distributions throughout the United States, for example *H. hamata* ranges from Mexico to Canada, and from California to Georgia (Rasmussen and Morse 2016).

5.3.3.2 Palearctic Distributions

Although species from the Palearctic zoogeographic region are not as common in the south-central United States as the Neotropical species, there were 8 species documented in this study that have Palearctic distributions. Polycentropodidae, Hydroptilidae, Brachycentridae, Limnephilidae, and Leptoceridae are the families that represent *Holocentropus picicornia, Agraylea multipunctata, Ithytrichia clavata, Brachycentrus americanus, Ecclisomyia conspersa, Onocosmoecus unicolor, Oecetis* *ochracea,* and *Triaenodes reuteri.* While *Ecclisomyia conspersa* and *Triaenodes reuteri* have distributions west of the Rockies, or Canada and adjacent states, respectively. The majority of these species have ubiquitous Nearctic distributions through Canada and the United States and some have transcontinental distributions that include Europe, Mongolia, Japan, Asia, and Russia (Rasmussen and Morse 2016). The transcontinental distribution of some of these species suggests present day distributions may reflect past geological events (e.g. Beringia). New Mexico has the most species with Palearctic distributions, and only *Ithytrichia clavata* is represented in more than one state. Louisiana is the only state that does not have any Palearctic species.

5.4 Caddisfly Demographics: Endemism and Species of Concern

A total of 454 caddisfly species representing 24 families and 93 genera were documented from the south-central United States. Similar caddisfly biodiversity studies conducted at the state or by physiographic region reported varying numbers of species, genera, and families. Ross (1944) reported 184 species from 17 families from Illinois; from the Interior Highlands Moulton and Stewart (1996) documented 229 species within 17 families and 58 genera; Houghton's Minnesota caddisfly biodiversity study documented 277 species representing 21 families and 75 genera (2010).

The lower number of species relative to land area, in comparison to other studies, of reported families, genera, and species from the south-central United States could be attributed to lack of suitable habitat, or the need for more sampling in under represented areas. The physiographic provinces of the Central Lowlands, Great Plains, Basin and Range, Colorado Plateaus, and the Southern Rocky Mountains are represented by surveys that contain low number of species. The majority of the Great Plains sampling is located in central Texas with little sampling in the Panhandle of the state. While it may appear that simply increasing the number of sampling locations would rectify the problem of under representation, much of the Great Plains region of the study area sees low annual precipitation (< 20 inches yearly). This natural ecological factor leads to a lower stream density in the region and many ephemeral water bodies. In order to determine if caddisflies inhabit these types of habitats sampling efforts would need to be timed with weather patterns to sample effectively. The low number of caddisfly species, genera, and families documented from Louisiana could be attributed to the types of water bodies present within the state. Bayous and rivers of Louisiana are often slow moving, with sandy or mud bottom substrate, and the influence of tidal waters through the southern coastal areas could limit the number of caddisfly species that are able to survive in these types of habitats.

5.4.1 Physiographic Province Endemism

A total of 18 endemic caddisfly species from 8 families were documented from the south-central United States. One-third of the endemic caddisflies are Hydroptilids “micro-caddisflies”, while 4 families are represented by only one endemic species. When considering the geographical “hotspot” for caddisfly endemism in the south-central United States, 50% of the endemic caddisflies are from Texas. No endemic species were reported from Oklahoma. In similar studies Houghton documented 3 endemic species in Minnesota (2010), while Moulton and Stewart (1996) documented 27 endemic species from the Interior Highlands.

5.4.1.1 Coastal Plain

Described by Fenneman (1938), Hunt (1974), and Walker and Coleman (1987) the Coastal Plain physiographic province extends from Massachusetts, to the Florida Keys, through east Texas and southward to Tamaulipas, Mexico. This area, with an elevation < 90 m, is known for its sluggish streams and bayous; and numerous marshes, swamps and lakes. The climate is humid, with annual average temperatures ranging from 15-21^{o}C and an annual precipitation of 40-60 inches. Due to the wet, acidic soils the primary vegetation is that of temperate rainforests with several species of pine, bald cypress (*Taxodium distichum*), oaks and members of the magnolia family. Understory vegetation includes ferns, palms, shrubs, and herbaceous plants (Bailey 1980).

The Coastal Plain has been described as a biological hotspot based on the definition of a region with > 1,500 endemic plant species and > 70% habitat loss (Noss et al. 2015). Of the more than 5,000 native vascular plants in the region, 1,816 are endemic (29%) (Noss et al. 2015). Likewise, endemic species are documented for freshwater fish (83 species), amphibians (44 species), reptiles (80 species), and mammals (70 species) (Noss et al. 2015). One endangered bird species resides within region, the red-cockaded woodpecker (*Leuconotpicus borealis*)(Bailey 1980).

The Coastal Plain is subdivided into 3 sections: East Gulf Coast Plain, Mississippi Alluvial Plain, and the West Gulf Coastal Plain. Endemic caddisfly species for the Coastal Plain division have been recorded from within the West Coastal Plain section and consist of one hydropschid, two glossosomatids, and two hydroptilids. Three species have all records from the south-central United States within the West

Gulf Coastal Plain: *Diplectrona rossi* (Hydropsychidae)(Louisiana), *Hydroptila abbotti* (Hydroptilidae)(Texas), and *Protoptila arca* (Glossosomatidae)(Texas). The remaining species: *Agapetus medicus* (Glossosomatidae)(Arkansas) and *Neotrichia juani* (Hydroptilidae)(Texas) will be discussed in the sections where the majority of their records were recorded. Species distributional maps are provided in Appendix D.

D. rossi was collected from a single location: Schoolhouse Springs in Jackson Parish, LA. This location consists of five small springs, of clear, cool water. *D. rossi* is a sister species to *D. modesta* which ranges easterly from Florida to New Hampshire and Quebec to Illinois to western Arkansas, northern Louisiana and southern Mississippi (Morse and Barr 1990).

H. abbotti was collected in Anderson County, Texas from the Engeling Wildlife Management Area. The type locality is a first order, spring-fed, sandy bottom stream in east Texas. *H. abbotti* belongs to the *H. waubesiana* group and is most closely related to *H. homochitta* (Moulton and Harris 1997).

P. arca was collected from the San Marcos River in Harris County, Texas. This is the type locality for this species described in 1961 by Edwards and Arnold. Hall (1950) describes a specimen as *Glossosoma* sp. from this same locality, but Edwards and Arnold (1961) suspect this specimen was likely *P. arca*. This species is most closely related to *P. piacha* (Mosely 1954) from Chiapas, Mexico.

5.4.1.2 Interior Plains: Edwards Plateau and Central Texas

The Edwards Plateau and Central Texas physiographic sections are placed within the Interior Plains, which extend from Canada to Texas in the central portion of the United States (Fennenman 1917). The Edwards Plateau is known for its limestone streams, and steep walled box canyons (BEG 1996). Located just to the north is Central Texas with granite hills and elevations of 120-180 meters (BEG 1996). Precipitation averages 20-40 inches annually in the region.

The majority of the endemic caddisflies of the Great Plains were collected in the Edwards Plateau, but a few species have records from Central Texas and in a few instances some are reported further east in the Western Gulf Coastal Plain. There are three species of endemic caddisflies: one hydroptilid, and one species from Ecnomidae and Xiphocentronidae. Distributional maps for the following species are located in Appendix D.

Neotrichia juani (Hydroptilidae) was primarily recorded from locations in the Edwards Plateau, however a few records are reported from Central Texas and the West Gulf Coastal Plain physiographic sections. This species is part of the *Neotrichia canixa* group, which is comprised of seven species (Harris and Tiemann 1993). Harris and Tiemann (1993) considered this group to be of Neotropical origins given that several species have distributions in Mexico, Central America through South America. *N. juani* was collected from perennial and ephemeral rivers, as well as small, spring-fed streams (Harris and Tiemann 1993).

Ecnomidae is a family of caddisflies represented on every continent, with the exception of Antarctica. The genus *Austrotinodes* is documented from Mexico, Central America, and Chile (Bowels 1995, Wiggins 1996). The only species of this genus reported from North America is *Austrotinodes texensis*, and it is closely related to *A.*

sedmani from Central America. This species is associated with karst springs of the Edwards Plateau (Bowels 1995).

Species of Xiphocentronidae are primarily distributed through Asia, Africa, Central and South America. Central American lineages have given rise to genera that are located in the southern United States, *Cnodocentron* in Arizona and *Xiphocentron* from Texas (Wiggins 1996, 2004). Species of *Xiphocentron* occur in Mexico, the Antilles, and Central and South America (Wiggins 1996). *X. messapus* records are primarily documented from the Edwards Plateau, however there are a few records from the boarder of the Edwards Plateau where it meets the physiographic sections of Central Texas and the West Gulf Coastal Plain. Edwards originally named the species, *X. mexico* (Wiggins 1996). Larvae inhabit spring fed streams in the Edwards Plateau.

5.4.1.3 Interior Highlands: Ouachita and Ozark Plateau

Fenneman (1917) established the boundary of the Ouachita and Ozark Plateau as physiographic provinces within the larger division of the Interior Highlands. While the Ouachita and the Ozark Plateau's are tectonically unique from each other, biological evidence gives rise to the suggestion that these two provinces were once connected (Moulton and Stewart 1996). The Ouachita physiographic province spans portions of Arkansas and Oklahoma, while the Ozark Plateau encompasses portions of Arkansas, Oklahoma, Missouri and Illinois (Fenneman 1917, Moulton and Stewart 1996). The highest elevations within the mountain ranges of the Ozark Plateau and Ouachita are 610 m and 860 m, respectively (Moulton and Stewart 1996). Average annual precipitation ranges from 35-60 inches; annual average temperature is between 4-15^{o}C

(Bailey 1980). Major vegetation is temperate deciduous forest dominated by broadleaf trees like oak (*Quercus* spp.), beech (*Fagus* spp.), birch (*Betula* spp.), hickory (*Carya* spp), walnut (*Juglans* spp.), maple (*Acer* spp.), elm (*Ulmus* spp.) and ash (*Fraxinus* spp.). In forests, thick layers of leaves and humus are prevalent.

Zollner et al. (2005) documented 36 endemic vascular plants for the Interior Highlands. The vast majority of the Interior Highlands endemic plants (81%) occur within the Ouachita Mountains. However, 14 taxa (39%) are only reported from the Ouachita Mountains, and 7 taxa (19%) are within the Ozark Plateau. There are 15 taxa (42%) that are found in both these physiographic provinces. Allen (1990) states that there are over 200 endemic species of plants and animals within the Interior Highlands, with one-third being insects. Twenty-seven endemic caddisflies of the Interior Highlands were documented and discussed by Moulton and Stewart (1996).

The Interior Highlands physiographic division is divided into two provinces the Ouachita and the Ozark Plateau. There are 4 physiographic sections within these provinces. However, the endemic caddisfly records for this region are predominately from one section, the Ouachita Mountains. There are 4 endemic caddisfly species reported from the Arkansas portions of the Ouachita/Ozark Plateau, one species is from each of the following families: Glossosomatidae, Hydropsychidae, Hydroptilidae, and Polycentropodidae. Distributional maps for each species are provided in Appendix D.

Agapetus medicus (Glossosomatidae) was primarily collected from the Ouachita Mountains with a few records reported from the Coastal Plain province that is to the east of the Ouachita and Ozark Plateau. Ross (1956) places this species within the *Agapetus "Celatus Group"* with 22 additional species reported from mountainous regions of the United States. Within the Ozark and Ouachita Mountains this species occurs in perennial or ephemeral, headwater streams (Moulton and Stewart 1996). *A. medicus* closely resembles *A. avitus* and *A. iridis* (Morse et al. 1989, Etnier et al. 2010).

Cheumatopsyche robisoni (Hydropsychidae) was collected from the Ouachita Mountains of Arkansas. *C. robisoni* is restricted to spring habitats within the Ouachita Mountains (Moulton and Stewart 1996). *C. robisoni* is closely related to *C. rossi* an endemic species found in the Ouachita and Ozark Mountains of Arkansas and Missouri. Moulton and Stewart (1996) suggest that phylogenetic studies should be investigated to determine the lineage of *C. robisoni* in relation to *Cheumatopsyche* spp. in the *C. rossi* group.

Paucicalcaria ozarkensis (Hydroptilidae) was collected from the Ouachita and Ozark Plateau provinces. Mathis and Bowles (1989) described the genus and species from specimens collected in an intermittent stream near Mount Magazine, Arkansas. This genus is a member of the subfamily Hydroptilinae and the Hydroptilini tribe and is most closely related to the genus *Hydroptila* (Mathis and Bowles 1989).

Polycentropus stephani records were reported from the Ouachita and Ozark Plateau and the various physiographic sections found within these provinces. This species was described in 1993 by Bowles et al. and is considered to be similar to *P. chelatus* (Moulton and Stewart 1996). No life history information is known currently about this species (Moulton and Stewart 1996), but Bowels et al. (1993) speculated that the larval habitat is most likely small, ephemeral streams.

5.4.1.4 Basin and Range: Mexican Highlands

This physiographic province extends from southern Oregon, Nevada, Arizona, New Mexico into southwest Texas (Fenneman 1917). It includes the mountain ranges that are flanked by the American Desert to the west and the Chihuahuan Desert to the east. Mountain elevations can reach as high as 2,700 meters. It is a semi-arid region, with the majority of the rainfall coming during the summer months. Average annual temperatures are 13-21 ^{o}C, but summer days can become hot, with extreme cold temperatures during the winter (Bailey 1980). Vegetation ranges from cacti in the desert region to grasslands in the high plains. Common vegetation includes Mesquite (*Prosopis* sp.) and *Yucca* spp (Bailey 1980).

The majority of the caddisfly records for this region were collected in the Big Bend and the Guadalupe Mountain National Parks. Several endangered species are listed for Big Bend (www.nps.gov/bibe/learn/nature/endangered), but no invertebrates are listed for the area. Four species of endemic caddisflies were collected from the Basin and Range province, specifically the Mexican Highland and Sacramento sections. The Mexican Highland section is the area along the southern border of Texas and New Mexico, and the Sacramento area is where the Guadalupe Mountains are located. Three species are hydroptilds, and the remaining species is a limnephelid (distributional maps Appendix D).

Neotrichia sonora (Hydroptilidae) were collected from the Mexican Highlands. This species is most closely related to *N. okopa* (Ross 1944). Species in this genus are more numerous in the subtropical and tropical regions (Blickle 1979). Twenty-four species are documented in North America, with one-fourth being state endemics

(Rasmussen and Morse 2016). Baumgardner and Bowels (2005) documented specimens of *N. sonora* collected primarily from small, mountain springs.

The genus *Ochrotrichia* is currently subdivided into two subgenera, *Ochrotrichia* and *Paratrichia* (TWC 2017). The subgenus *Ochrotrichia* has a distribution ranging throughout North America, to northern South America, and the Antilles (Harris and Moulton 1993). New species of *Ochrotrichia* described since Marshall's review of the Hydroptilidae are primarily from Neotropical regions (Harris and Moulton 1993). *Ochrotrichia boquillas* (Hydroptilidae) specimens were only collected from within the Mexican Highlands. This species is associated with the *O. xena* group and is most closely related to *O. flagellata* and *O. pectinata* (Moulton and Harris 1997). Specimens were collected within the Big Bend National Park and surrounding area. *O. guadalupensis* were collected from the Guadalupe Mountain National Park (Sacramento physiographic section). This species is most similar to *O. argentea*, *O. rothi*, and *O. alexanderi* (Harris and Moulton 1993).

Limnephilus adapus (Limnephilidae) specimens were collected from the Mexican Highlands and are most closely related to the *spinatus* group and to *L. spinatus* itself (Ross 1950).

5.4.1.5 Great Plains: Raton

The Raton Basin occupies sections of northeastern New Mexico and southeastern Colorado (Fenneman 1917, McGinnis 1956). Elevational relief can vary from less than 7,500 feet to over 12,000 feet. Rainfall can equal 20 inches annually for mountainous regions below the timberline. As elevation decreases the annual rainfall averages 17 inches or less. Vegetation such as pines (*Pinus* spp.), spruce (*Picea* spp.), juniper (*Juniperus* spp.), and pinyon (*Pinus* spp.) are common at higher elevations (McGinnis 1956).

One species of Hydropsychidae was documented to be endemic from this region, *Hydropsyche vanaca*. This species most closely resembles *H. bifida* (Denning 1965). Denning reported his specimen collections were from a single Sangre de Cristo Mountain stream (1956); this species has since been reported by Vieira et al. (2009) from a spring seep of Jaramallio Creek within the Valles Caldera National Preserve, Sandoval County, New Mexico.

5.4.2 Species of Concern

Thirteen caddisfly families representing 30 species from the south-central United States are of concern to federal or state agencies. No federal species of concern have been listed, but at least two have been petitioned or considered as candidates for listing under the endangered species act. Arkansas, Louisiana, and Texas report most caddisfly species of concern at the S1 “critically imperiled” or S2 “imperiled” status. Restricted ranges or unknown habitat requirements make these species vulnerable to local extirpation. Nearly half of all species of concern for the study area are “micro caddisflies” (Hydroptilidae), and 10 species of concern are also endemic to the study area.

5.5 Final Conclusions

The goal of this project was to document the biodiversity and biogeographic distribution of caddisflies from the south-central United States. A total of 446 species were previously documented from the region and this study added 2 additional species to the regional list; *Hydroptila scheiringi,* and *Mayatrichia tuscaloosa*. Eighteen species in the dataset are considered endemic and 30 species are of concern to federal or state agencies. This project was only possible because dozens of scientists and other associated personnel over the last century provided data to various natural history collections or published their efforts in peer-reviewed literature. As a consequence, this research highlights the scientific value of sharing study specimens and their associated data with other scientific professionals through natural history collections. On the other hand, this study reveals the many difficulties of utilizing this type of data to understand species distributions across a large geographic area. For example, data gaps may require targeted sampling efforts to fill them; access to data that is not electronic can be difficult to acquire; and lack of data verification.

The biogeographic pattern of caddisfly community structure across the south-central United States was assessed by comparing broad scale geographical factors to caddisfly community composition. Physiographic province was chosen as the best biogeographic variable because 1) the scale and resolution were most appropriate to the study area and 2) the reliance of physiographic province on geology provides ecological relevance in terms of stream chemistry. Community structure between the individual physiographic provinces was addressed through analyses that compared similarity in community composition between sites as well dissimilarity between provinces. On average, sites within any one province were more similar in community composition than sites in other provinces. Provinces with close geographical proximity were less dissimilar than provinces that were geographically isolated from one another.

This study highlights the connection between the south-central United States and the Neotropics in relation to caddisfly fauna. In particular these relationships raise questions concerning climate change effects upon species distributions and the potential to expand or retract due to changes in temperature or temperature mediated habitat conditions. The lack of life history studies for caddisflies and unknown larval-pupae-adult associations are areas of research that would benefit biogeographic studies such as this when distributions of species are discontinuous. This type of information would clarify the ecological factors that impact species distribution.

Baseline studies that document the geographic distribution of a large number of species contribute to our understanding of species evolutionary and ecological relationships. They provide data for monitoring future changes in species biodiversity and distributions. Lastly, identification of endemic species with limited distribution can help to target conservation efforts.

APPENDIX A

PUBLICATIONS USED FOR SPECIES IDENTIFICATIONS

Family	Genera	Species	Author(s)	Title
Beraeidae	*Beraea*	NA	Ross (1944)	*The Caddis Flies, or Trichoptera, of Illinois*
Brachycentridae	*Brachycentrus*	4	Houghton (2012); Moulton & Stewart (1996); Schmid (1983)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; REVISION DES TRICHOPTèRES CANADIENS: III. Les Hyalopsychidae, Psychomyiidae, Goeridae, Brachycentridae, Sericostomatidae, Helicopsychidae, Beraeidae, Odontoceridae, Calamoceratidae et Molannidae.*
	Micrasema	4	Houghton (2012); Moulton & Stewart (1996); Schmid (1983)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; REVISION DES TRICHOPTèRES CANADIENS: III. Les Hyalopsychidae, Psychomyiidae, Goeridae, Brachycentridae, Sericostomatidae, Helicopsychidae, Beraeidae, Odontoceridae, Calamoceratidae et Molannidae.*
Calamoceratidae	*Phylloicus*	1	Bowles & Flint (1997); Prather (2003)	*The genus Phylloicus Müller (Trichoptera: Calamoceratidae) in the United States, with a redescription of Phylloicus ornatus (Banks); Revision of the Neotropical caddisfly genus Phylloicus (Trichoptera: Calamoceratidae).*
Dipseudopsidae	*Phylocentropus*	3	Armitage & Hamilton (1990); Sturkie & Morse (1998); Houghton (2012)	*Diagnostic Atlas of the North American Caddisfly Adults II: Economidae, Polycentropodidae, Psychomyiidae, and Xiphocentronidae; Larvae of the three common North American species of Phylocentropus (Trichoptera: Dipseudopsidae); Biodiversity of Minnesota Caddisflies*
Economidae	*Austrotinodes*	1	Bowles (1995)	*A New Species of Austrotinodes (Trichoptera: Ecnomidae) from Texas*
Glossosomatidae	*Agapetus*	3	Denning (1948); Moulton & Stewart (1996); Etnier *et al.* (2010)	*New species of Trichoptera; Interior Highland Trichoptera; A review of the genus Agapetus Curtis (Trichoptera: Glossosomatidae) in eastern and central North America, with description of 12 new species*
	Culoptila	2	Schmid (1982)	*Revision des Trichoptères Canadiens: II. Les Glossosomatidae et Philopotamidae (Annulipalpia)*
	Glossosoma	3	Banks (1904); Nimmo (1974); Schmid (1982)	*The Neuropteroid insects from New Mexico; The adult Trichoptera (Insecta) of Alberta and Eastern British Columbia, and their post-glacial origins II: The familes Glossosomatidae and Philopotamidae; Revision des Trichoptères Canadiens: II. Les Glossosomatidae et Philopotamidae (Annulipalpia)*
	Protoptila	8	Ross (1941); Edwards & Arnold (1961); Schmid (1982); Houghton (2012)	*Descriptions and Records of North American Trichoptera; The caddisflies of the San Marcos River; Revision des Trichoptères Canadiens: II. Les Glossosomatidae et Philopotamidae (Annulipalpia); Biodiversity of Minnesota Caddisflies*
Helicopsychidae	*Helicopsyche*	6	Houghton (2012); Moulton & Stewart (1996); Schmid (1983); Johanson (2002)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; REVISION DES TRICHOPTèRES CANADIENS: III. Les Hyalopsychidae, Psychomyiidae, Goeridae, Brachycentridae, Sericostomatidae, Helicopsychidae, Beraeidae, Odontoceridae, Calamoceratidae et Molannidae; Revision of the Neotropical caddisfly subgenus Helicopsyche (Cochliopsyche) (Trichoptera, Helicopsychidae), with descriptions of twelve new species*
Hydrobiosidae	*Atopsyche*	2	Ross & King (1952)	*Biogeographic and Taxonomic studies in Atopsyche (Trichotpera, Rhyacophilidae).*
Hydropsychidae	*Arctopsyche*	1	Nimmo (1987)	*The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States*

Family	Genera	Species	Author(s)	Title
	Cheumatopsyche	25	Nimmo (1987); Houghton (2012); Gordon (1974); Moulton & Stewart (1996); Ross (1941, 1944, 1947)	*The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States; Biodiversity of Minnesota Caddisflies; A synopsis and phylogenetic outline of the Nearctic members of Cheumatopsyche; Interior Highland Trichoptera; Descriptions and Records of North American Trichoptera; The Caddis Flies, or Trichoptera, of Illinois; Three new caddisflies form the southern United States;*
	Diplectrona	2	Houghton (2012); Nimmo (1987); Morse & Barr (1990)	*Biodiversity of Minnesota Caddisflies; The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States; Unusual caddisfly (Trichoptera) fauna of Schoolhouse Springs, Louisiana, with description of a new species of Diplecrona (Hydropsychidae)*
	Homoplecta	1	Nimmo (1987)	*The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States; Biodiversity of Minnesota Caddisflies*
	Hydropsyche	25	Flint, Voshell & Parker (1979); Moulton & Stewart (1996); Ross (1941, 1944, 1947); Nimmo (1987); Houghton (2012); Flint (1972); Denning (1965)	*Hydropsyche scalaris group in Virginia, with the description of two new species (Trichoptera: Hydropsychidae); Interior Highland Trichoptera; The Caddis Flies, or Trichoptera, of Illinois; Descriptions and Records of North American Trichoptera; Descriptions and Records of North American Trichoptera, with synoptic notes; The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States; Biodiversity of Minnesota Caddisflies; Three new caddisflies from the southern United States; New Hydropsychidea (Trichoptera)*
	Leptonema	1	Flint *et al.* (1987)	*A Revision of the Genus Leptonema Guerin (Trichoptera: Hydropsychidae: Macronematinae).*
	Macrostemum	2	Nimmo (1987); Houghton (2012)	*The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States; Biodiversity of Minnesota Caddisflies*
	Parapsyche	1	Nimmo (1987)	*The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States; Biodiversity of Minnesota Caddisflies*
	Potamyia	1	Nimmo (1987)	*The adult Arctopsychidae and Hydropsychidae (Trichoptera) of Canada and adjacent United States; Biodiversity of Minnesota Caddisflies*
	Smicridea	3	Flint (1974)	*Studies of Neotropical caddiflis, XVII: the genus Smicridea from North and Central America (Trichoptera: Hydropsychidae)*
Hydroptilidae	*Agraylea*	2	Blickle (1979); Houghton (2012)	*Hydroptilidae (Trichoptera) of America North of Mexico; Biodiversity of Minnesota Caddisflies*
	Alisotrichia	1	Blickle & Denning (1977)	*New Species and a New Genus of Hydroptilidae (Trichoptera)*
	Dibusa	1	Moulton & Stewart (1996)	*Interior Highland Trichoptera*
	Hydroptila	42	Moulton & Harris (1997); Houghton (2012); Harris & Kelley (1984); Denning (1947); Moulton & Stewart (1996); Ross (1941, 1947); Sykora & Harris (1994); Blickle (1979);	*New species of southwestern Nearctic microcaddisflies (Trichoptera: Hydroptilidae); Biodiversity of Minnesota Caddisflies; New species of Hydroptilidae (Trichoptera) from Alabama; Hydroptilidae (Trichoptera) from southern United States; Interior Highland Trichoptera; Notes and descriptions of Nearctic Hydroptilidae (Trichoptera); Descriptions and Records of North American Trichoptera Hydroptilidae (Trichoptera) of*

Family	Genera	Species	Author(s)	Title
			Mosley (1937); Holzenthal & Kelley (1983); Flint, Englund & Kumashiro (2003)	*America North of Mexico; Five new species of Hydroptila from eastern United States (Insecta: Trichoptera: Hydroptilidae); Hydroptilidae (Trichoptera) of America north of Mexico; Mexican Hydroptilidae (Trichoptera); New micro-caddisflies from the southeastern United States (Trichoptera: Hydroptilidae); A reassessment and new state records of Trichoptera occurring in Hawaii with discussion on origins and potential ecological impacts.*
	Ithytrichia	3	Houghton (2012); Moulton & Stewart (1996); Moulton, Harris & Slusark (1999)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; The microcaddisfly Genus Ithytrichia Eaton (Trichoptera: Hydroptilidae) in North America.*
	Leucotrichia	3	Flint (1970); Houghton (2012)	*Studies of Neotropical caddisflies, X: Leucotrichia and related genera from North and Central America; Biodiversity of Minnesota Caddisflies;*
	Mayatrichia	3	Ross (1944); Houghton (2012); Moulton & Stewart (1996)	*The Caddis Flies, or Trichoptera, of Illinois; Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera*
	Metrichia	1	Moulton & Stewart (1996)	*Interior Highland Trichoptera*
	Neotrichia	15	Moulton & Stewart (1996); Harris & Rasmussen (2010); Mosely (1937); Harris & Tiemann (1993); Houghton (2012); Ross (1944)	*Interior Highland Trichoptera; The Neotrichia caxima Group (Trichoptera: Hydroptilidae) in the southeastern United States; Mexican Hydropitlidae (Trichotpera); New species of Neotrichia from Texas and Panama, with preliminary review of the N. canixa group (Trichoptera: Hydroptilidae); Biodiversity of Minnesota Caddisflies; The Caddis Flies, or Trichoptera, of Illinois*
	Ochrotrichia	26	Moulton & Stewart (1996); Denning & Blickle (1972); English & Hamilton (1986); Moulton & Harris (1997); Ross (1944); Flint (1965); Harris & Moulton (1993); Blickle (1979); Ross (1941); Denning & Blickle (1972); Houghton (2012)	*Interior Highland Trichoptera; A Review of the Genus Ochrolrichia (Trichoptera: Hydroptilidae); Hydroptilidae (Trichoptera) of America North of Mexico; The Larva of Ochrotrichia arizonica (Trichoptera: Hydroptilidae) with Notes on Distribution and Geographic Variation; New species of southwestern Nearctic microcaddisflies (Trichoptera: Hydroptilidae); The Caddis Flies, or Trichoptera, of Illinois; New species of Trichoptera from the United States; Descriptions and Records of North American Trichoptera; New species of Ochrotrichia (Ochrotrichia) from the southwestern United States and Northern Mexico (Trichoptera: Hydroptilidae); A review of the Genus Ochrotrichia (Trichoptera: Hydroptilidae); Biodiversity of Minnesota Caddisflies*
	Orthotrichia	5	Houghton (2012); Moulton & Stewart (1996)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera*
	Oxyethira	23	Blickle (1979); Moulton & Stewart (1996); Houghton (2012); Kelley (1981, 1985); Flint (1991); Mosley (1937)	*Hydroptilidae (Trichoptera) of America North of Mexico;Interior Highland Trichoptera; Biodiversity of Minnesota Caddisflies; New species of Oxyethira (Trichoptera: Hydroptilidae) from the southeastern United States; Revision of the micro-caddisfly genus Oxyetheria (Trichoptera: Hydroptilidae); Studies of Neotropical Caddiflies, XLV: The taxonomy, phenology, and faunistics of the Trichoptera of Antioquia, Columbia; Mexican Hydroptilidae (Trichoptera)*

Family	Genera	Species	Author(s)	Title
	Paucicalcaria	1	Moulton & Stewart (1996)	*Interior Highland Trichoptera*
	Stactobiella	2	Houghton (2012)	*Biodiversity of Minnesota Caddisflies;*
	Zumatrichia	1	Flint (1970)	*Studies of Neotropical caddisflies, X: Leucotrichia and related genera from North and Central America*
Lepidostomatidae	*Lepidostoma*	18	Weaver (1988); Houghton (2012); Banks (1907); Moulton & Stewart (1996); Ross (1941); Flint & Wiggins (1961);	*A synopsis of the North American Lepidostomatidae (Trichoptera); Biodiversity of Minnesota Caddisflies; Descriptions of New Trichoptera; Interior Highland Trichoptera; Descriptions and Records of North American Trichoptera; Records and descriptions of North American species in the Genus Lepidostoma, with a revision of the Vernalis Group (Trichoptera: Lepidostomatidae).*
Leptoceridae	*Ceraclea*	14	Houghton (2012); Whitlock & Morse (1994); Moulton & Stewart (1996); Morse (1975)	*Biodiversity of Minnesota Caddisflies; Ceraclea enodis, a new species of spongefeeding caddisfly (Trichoptera: Leptoceridae); Interior Highland Trichoptera; A phylogeny and revision of the caddisfly genus Ceraclea (Trichoptera: Leptoceridae)*
	Lepotcerus	1	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Mystacides	1	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Nectopsyche	10	Houghton (2012); Moulton & Stewart (1996)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera*
	Oecetis	14	Houghton (2012); Moulton & Stewart (1996); Ross (1941)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; Descriptions and Records of North American Trichoptera;*
	Setodes	2	Holzenthal (1982)	*The Caddisfly Genus Setodes in North America (Trichoptera: Leptoceridae)*
	Triaenodes	15	Houghton (2012); Moulton & Stewart (1996); Ross (1944); Flint (1966)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; The Caddis Flies, or Trichoptera, of Illinois; Notes on certain Nearctic Trichoptera in the Museum of Comparativie Zoology*
Limnephilidae	*Amphicosmoecus*	1	Nimmo (1971)	*Adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin*
	Anabolia	2	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Chyranda	1	Nimmo (1971)	*Adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin*
	Clistoronia	2	Nimmo (1971)	*Adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin*
	Dicosmoecus	1	Nimmo (1971)	*Adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin*
	Ecclosomyia	1	Nimmo (1971)	*Adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin*
	Frenesia	1	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Hesperophylax	4	Nimmo (1971); Houghton (2012); Parker & Wiggins (1987)	*Adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin; Biodiversity of Minnesota Caddisflies; Revision of the Caddisfly Genus Psilotreta (Trichoptera: Odontoceridae).*
	Homophylax	1	Denning (1963)	*The Genus Homophylax (Trichoptera: Limnephilidae)*
	Ironoquia	2	Ross (1944); Houghton (2012)	*The Caddis Flies, or Trichoptera, of Illinois; Biodiversity of Minnesota Caddisflies;*

Family	Genera	Species	Author(s)	Title
	Limnephilus	14	Ross (1938, 1944, 1950); Ross & Merkley (1952); Nimmo (1971, 1991); Houghton (2012)	*Descriptions of new North American Trichoptera; The Caddis Flies, or Trichoptera, of Illinois; Synoptic notes on some Nearctic Limnephildae caddisflies (Trichoptera: Limnephilidae); An Annotated Key to the Nearctic males of Limnephilus (Trichoptera: Limnephilidae); Adult Rhyacophilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin; Seven new species of Limenphilus from western North America with descriptions of female of L. pallens (Banks) (Trichoptera, Limnephilidae, Limnepilinae, Limnephilini); Biodiversity of Minnesota Caddisflies*
	Onocosmoecus	1	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Platycentropus	2	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Psychoglypha	1		
	Psychoronia	2	Ruiter (1999); Wiggins (1975)	*A new species and new synonym in the genus Psychoronia (Limnephilidae), with significant records for caddisflies (Trichoptera) from western North America; Contricutions to the systematics of the caddisfly family Limnephilidae (Trichoptera). II.*
	Pycnopsyche	7	Moulton & Stewart (1996); Houghton (2012); Weaver 1988	*Interior Highland Trichoptera; Biodiversity of Minnesota Caddisflies; A synopsis of the North American Lepisotomatidae (Trichoptera).*
Molannidae	*Molanna*	5	Houghton (2012); Moulton & Stewart (1996)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera*
Odontoceridae	*Marila*	2	Moulton & Stewart (1996)	*Interior Highland Trichoptera*
Philoptamidae	*Chimarra*	16	Armitage (1996); Houghton (2012); Denning (1962)	*Diagnostic atlas of the North American caddisfly adults. I: Philopotamidae (3rd ed); Biodiversity of Minnesota Caddisflies; New Trichoptera from Mexico.*
	Dolophilodes	1	Nimmo (1974)	*The adult Trichoptera (Insecta) of Alberta and eastern British Columbia, and their post-glacial origins. II. The families Glossosomatidae and Philopotamidae.*
	Wormalidia	4	Armitage (1996); Nimmo (1974); Houghton (2012)	*Diagnostic atlas of the North American caddisfly adults. I: Philopotamidae (3rd ed).; The adult Trichoptera (Insecta) of Alberta and eastern British Columbia, and their post-glacial origins. II. The families Glossosomatidae and Philopotamidae; Biodiversity of Minnesota Caddisflies;*
Phyryagenidae	*Agrypnia*	2	Houghton (2012); Wiggins (1998)	*Biodiversity of Minnesota Caddisflies; The Caddisfly Family Phrygaenidae (Trichoptera)*
	Banksiola	1	Houghton (2012); Wiggins (1998)	*Biodiversity of Minnesota Caddisflies; The Caddisfly Family Phrygaenidae (Trichoptera)*
	Fabria	1	Houghton (2012); Wiggins (1998)	*Biodiversity of Minnesota Caddisflies; The Caddisfly Family Phrygaenidae (Trichoptera)*
	Phryganea	1	Houghton (2012); Wiggins (1998)	*Biodiversity of Minnesota Caddisflies; The Caddisfly Family Phrygaenidae (Trichoptera)*
	Ptilostomis	3	Houghton (2012); Moulton & Stewart (1996); Wiggins (1998)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; The Caddisfly Family Phrygaenidae (Trichoptera)*
Polycentropodidae	*Cernotina*	4	Armitage & Hamilton (1990); Nimmo (1986)	*Diagnostic Atlas of the North American caddisfly adults II: Economidae, Polycentropodidae, Psychomyiidae and*

Family	Genera	Species	Author(s)	Title
				Xiphocentronidae; The Adult Polycentropodidae of Canada and adjacent United States
	Cyrnellus	1	Nimmo (1986)	*The Adult Polycentropodidae of Canada and adjacent United States*
	Holocentropus	1	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Neureclipsis	3	Houghton (2012); Armitage & Hamilton (1990)	*Biodiversity of Minnesota Caddisflies; Diagnostic Atlas of the North American caddisfly adults II: Economidae, Polycentropodidae, Psychomyiidae and Xiphocentronidae*
	Nyctiphylax	5	Houghton (2012); Armitage & Hamilton (1990)	*Biodiversity of Minnesota Caddisflies; Diagnostic Atlas of the North American caddisfly adults II: Economidae, Polycentropodidae, Psychomyiidae and Xiphocentronidae*
	Plectocnemia	16	Houghton (2012); Nimmo (1986); Armitage & Hamilton (1990); Moulton & Stewart (1996)	*Biodiversity of Minnesota Caddisflies; The Adult Polycentropodidae of Canada and adjacent United States; Diagnostic Atlas of the North American caddisfly adults II: Economidae, Polycentropodidae, Psychomyiidae and Xiphocentronidae; Interior Highland Trichoptera;*
Psychomyiidae	*Lype*	1	Houghton (2012);	*Biodiversity of Minnesota Caddisflies;*
	Paudinella	1	Armitage & Hamilton (1990)	*The Adult Polycentropodidae of Canada and adjacent United States; Diagnostic Atlas of the North American caddisfly adults II: Economidae, Polycentropodidae, Psychomyiidae and Xiphocentronidae;*
	Psycomyia	1	Houghton (2012)	*Biodiversity of Minnesota Caddisflies;*
Ptilocolepidae	*Paleagapetus*	1	Blickle (1979)	*Hydroptilidae (Trichoptera) of America north of Mexico*
Rhyacophilidae	*Rhyacophila*	11	Houghton (2012); Moulton & Stewart (1996); Nimmo (1971)	*Biodiversity of Minnesota Caddisflies; Interior Highland Trichoptera; The adult Rhyacohilidae and Limnephilidae (Trichoptera) of Alberta and eastern British Columbia and their post-glacial origin*
Sericostomatidae	*Agarodes*	3	Keth & Harris (2008); Houghton (2012)	*The North American genus Agarodes Banks (Trichoptera: Sericostomatidae); Biodiversity of Minnesota Caddisflies*
Thremmatidae	*Neophylax*	2	Houghton (2012)	*Biodiversity of Minnesota Caddisflies*
	Oligophlebodes	2	Ross (1944)	*The Caddis Flies, or Trichoptera, of Illinois*
Xiphocentronidae	*Xiphocentron*	2	Armitage & Hamilton (1990)	*The Adult Polycentropodidae of Canada and adjacent United States; Diagnostic Atlas of the North American caddisfly adults II: Economidae, Polycentropodidae, Psychomyiidae and Xiphocentronidae;*

APPENDIX B

PHYLOGENETIC TRICHOPTERA SPECIES LIST COMPLIED FROM NATURAL HISTORY COLLECTION RECORDS AND CONTEMPORARY SAMPLING. SPECIES OF CONCERN FROM FEDERAL OR LOCAL AGENCIES ARE INDICATED USING THE INITIALS OF EACH AGENCY

- (X*) Indicates species or locations reported from published accounts only.
- (**X**) Indicates a new distributional record from NHC records
- (**-X-**) Indicates a new distributional record from specimens collected during 2011-2016
- (**bold**) Species name indicates a species not previously reported from study area
- Species of concern that are listed with these federal or state agencies: USFW (U.S. Fish and Wildlife Department), TPWD (Texas Parks and Wildlife Department), LDWF (Louisiana Department of Wildlife and Fisheries) and ANHC (Arkansas Natural Heritage Commission).
- Grey shaded species indicates endemic to the state
- Superscripts of NT (Neotropical) or PL (Palearctica) indicate species ranges outside of Nearctica

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
Suborder Annulipalpia Superfamily PHILOPOTAMOIDEA Family **Philopotamidae**							
Subfamily Chimarinae	*Chimarra adella*					X	
	Chimarra angustipennis ^{NT}	X		**X**	X	X	
	Chimarra aterrima ^{NT}	X	X		X	X	
	Chimarra barranca ^{NT}					X	
	Chimarra beameri ^{NT}					X	
	Chimarra elia ^{NT}					X	
	Chimarra feria	X			X	X	
	Chimarra florida		X				
	Chimarra holzenthali		X			X	USFW, TPWD, LDWF
	Chimarra moselyi		X			X	
	Chimarra obscura	X	**X**		X	X	
	Chimarra parasocia	X	X			X	
	Chimarra ridleyi ^{NT}			X		X	
	Chimarra socia	X	X			**X**	
	Chimarra texana ^{NT}					X	
	Chimarra utahensis			X			

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
Subfamily Philopotaminae	*Dolophilodes aequalis*			X			
	Dolophilodes novusamericanus			**X**			
	Wormaldia arizonensis [NT]			**X**		X	TPWD
	Wormaldia gabriella			**X**			
	Wormaldia moesta	X			X		
	Wormaldia strota	X			X		
Superfamily HYDROPSYCHOIDEA Family **Ecnomidae**							
	Austrotinodes texensis					X	USFW, TPWD
Family **Dipseudopsidae**							
Subfamily Hyalopsychinae	*Phylocentropus carolinus*		X				
	Phylocentropus harrisi					X	TPWD
	Phylocentropus lucidus		X				
	Phylocentropus placidus	X	X		X	X	
Family **Xiphocentronidae**							
Subfamily Xiphocentroninae	*Xiphocentron messapus*					X	TPWD
Family **Psychomyiidae**							
Subfamily Psychomyinae	*Paduniella nearctica*	X					USFW, ANHC
	Psychomyia flavida [PL]	X		**X**	X		
Subfamily Tinodinae	*Lype diversa*	X	X			X	
Family **Polycentropodidae**							
Subfamily Polycentropodinae	*Cernotina astera* [NT]			**-X-**		X	
	Cernotina calcea [NT]	X	X	**-X-**	X	X	
	Cernotina oklahoma			**X**	X	X	
	Cernotina spicata	X	X		X	X	
	Cyrnellus fraternus [NT]	X	X	**-X-**	X	X	
	Holocentropus flavus				X*	X*	
	Holocentropus picicornis [PL]				**X**		
	Neureclipsis crepuscularis	X	X		X	X	

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Neureclipsis melco		X			X	
	Neureclipsis piersoni	X*					
	Nyctiophylax affinis	X	X		X	X	
	Nyctiophylax celta	X*					
	Nyctiophylax moestus	X*			X*		
	Nyctiophylax neotropicalis NT	**X**					
	Nyctiophylax serratus	X	**X**		X	X	
	Nyctiophylax vestitus	**X**					
	Plectrocnemia cinerea	X	X		X	X	
	Plectrocnemia crassicornis	X	X		X	X	
	Plectrocnemia nascotia				X*	X*	
	Plectrocnemia remota	**X**					
	Polycentropus arizonensis			X			
	Polycentropus centralis	X			X	X	
	Polycentropus confusus	X			X		
	Polycentropus gertschi			**X**		X	
	Polycentropus halidus			X		X	
	Polycentropus harpi	X			X	X	
	Polycentropus picana					X	
	Polycentropus stephani	X					
	Polycentropus variegatus			**X**			
	Polyplectropus charlesi					X	
	Polyplectropus misjola					X	
	Polyplectropus santiago NT					X	
Family **Hydropsychidae**							
Subfamily Arctopychinae	*Arctopsyche grandis*			X			
	Parapsyche almota			X*			
Subfamily Diplectoninae	*Diplectrona metaqui*		**X**				
	Diplectrona modesta	X	**X**		X	X	
	Diplectrona rossi		X				USFW, LDWF
	Homoplectra doringa	X					

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
Subfamily Hydropsychinae	*Cheumatopsyche analis*	X	X	**X**	**-X-**	**X**	
	Cheumatopsyche aphanta	X	**-X-**		X	X	
	Cheumatopsyche arizonensis [NT]			X		X	
	Cheumatopsyche burksi	X	X		X	X	
	Cheumatopsyche campyla	X		X	X	X	
	Cheumatopsyche comis			X	X	X	
	Cheumatopsyche harwoodi enigma	X					
	Cheumatopsyche enonis			X			
	Cheumatopsyche gracilis	X			X		
	Cheumatopsyche halima	X					
	Cheumatopsyche harwoodi	**X**			**X**		
	Cheumatopsyche helma	X					
	Cheumatopsyche lasia [NT]	X		X	X	X	
	Cheumatopsyche minuscula	X			X		
	Cheumatopsyche mollala	X					
	Cheumatopsyche morsei		X			X	USFW, TPWD, LDWF
	Cheumatopsyche oxa	X			X	**X**	
	Cheumatopsyche pasella	X	X		X	X	
	Cheumatopsyche pinaca		X				
	Cheumatopsyche pinula [NT]			X			
	Cheumatopsyche robisoni	X					
	Cheumatopsyche rossi	X			X		
	Cheumatopsyche smithi				X	X	
	Cheumatopsyche sordida	X	X		X	X	
	Cheumatopsyche speciosa	X			X		
	Cheumatopsyche virginica		X				
	Hydropsyche alvata	X	X	X	X	**X**	
	Hydropsyche arinale	X			X		
	Hydropsyche auricolor [NT]			X		X	
	Hydropsyche betteni	X	X		X		
	Hydropsyche bidens	X			X	X	

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Hydropsyche bronta	X		**X**	X		
	Hydropsyche californica			X			
	Hydropsyche carolina					**X**	
	Hydropsyche cockerelli			X			
	Hydropsyche decalda		X			X	
	Hydropsyche delrio NT					X	
	Hydropsyche elissoma		X				
	Hydropsyche incommoda	X	X		**X**	**X**	
	Hydropsyche mississippiensis		X			X	
	Hydropsyche morosa	X			X		
	Hydropsyche occidentalis			X			
	Hydropsyche orris	X	X	**X**	X	X	
	Hydropsyche oslari NT			X		X	
	Hydropsyche piatrix	X					
	Hydropsyche placoda	**X**	**X**				
	Hydropsyche rossi	X	X		X	X	
	Hydropsyche scalaris	X		X*	X	X	
	Hydropsyche simulans	X			X	X	
	Hydropsyche solossonae	X					
	Hydropsyche sparna		**X**				
	Hydropsyche tana			**X**			
	Hydropsyche vanaca			X			
	Hydropsyche venada			X			
	Potamyia flava	X	X		X	X	
Subfamily Macronematinae	*Leptonema albovirens* NT					X*	
	Macrostemum carolina	X	X		X	X	
	Macrostemum zebratum	**X**					
Subfamily Smicrideninae	*Smicridea dispar* NT					**X**	
	Smicridea fasciatella NT			X	X	X	
	Smicridea signata NT			X	X	X	
Suborder “Spicipalpia”							

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
Super family HYDROPTILOIDEA Family **Glossosomatidae**							
Subfamily Agapetinae	*Agapetus boulderensis*			X			
	Agapetus illini	X			X		
	Agapetus medicus	X					USFW, ANHC
	Agapetus minutus			**X**			
Subfamily Glossosomatinae	*Glossosoma parvulum*			X			
	Glossosoma ventrale NT			X			
	Glossosoma verdonum			X*			
Subfamily Protptilinae	*Culoptila cantha*			X	**X**	X	
	Culoptila thoracica NT			X			
	Protoptila alexanderi NT					X	
	Protoptila arca					X	USFW, TPWD
	Protoptila balmorhea					X	USFW, TPWD
	Protoptila erotica			X			
	Protoptila lega	X			X		
	Protoptila maculata	X			X	X	
	Protoptila tenebrosa	X			X		
Family **Hydrobiosidae**							
Subfamily Hydrobiosinae	*Atopsyche erigia* NT					X	
	Atopsyche sperryi NT			X			
Family **Rhyacophilidae**							
Subfamily Rhyacophilinae	*Rhyacophila angelita*			X*			
	Rhyacophila banksi	X					
	Rhyacophila brunnea			X			
	Rhyacophila coloradensis			X			
	Rhyacophila fenestra	X					
	Rhyacophila glaberrima	X					
	Rhyacophila hyalinata			X*			
	Rhyacophila kiamichi	X			X		
	Rhyacophila lobifera	X*			X*		

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Rhyacophila pellisa			X			
	Rhyacophila vofixa			**<u>X</u>**			
Family **Hydroptilidae**							
Subfamily Hydroptilinae	*Agraylea costello*	X*					
	Agraylea multipunctata [PL]			X			
	Hydroptila abbotti					X	
	Hydroptila acuminata [NT]					X	
	Hydroptila ajax [NT]		**-X-**		X	X	
	Hydroptila alabama					X	
	Hydroptila albicornis	X			X		
	Hydroptila amoena	X	**<u>X</u>**		X		
	Hydroptila angusta [NT]	X		X	X	X	
	Hydroptila arctia [NT]			X		X	
	Hydroptila armata	X			X	X	
	Hydroptila artesa	X					
	Hydroptila berneri	X	X*			X	
	Hydroptila broweri	X					
	Hydroptila consimilis	X	**<u>X</u>**	X	X	X	
	Hydroptila delineata	X					
	Hydroptila denza [NT]			X*			
	Hydroptila grandiosa	X			X	X	
	Hydroptila hamata [NT]	X	X	X	X	X	
	Hydroptila icona [NT]			X	X	X	
	Hydroptila llogannae		X*			X	
	Hydroptila maculata		**<u>X</u>**				
	Hydroptila melia				X	X	TPWD
	Hydroptila mexicana [NT]	**<u>X</u>**					
	Hydroptila modica [NT]			X		X	
	Hydroptila molsonae		X				LDWF
	Hydroptila novicola	**<u>X</u>**	X			X	
	Hydroptila oneili	X*					

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Hydroptila ouachita		X			X	USFW, TPWD, LDWF
	Hydroptila pecos			X	**X**	X	
	Hydroptila perdita	X			X		
	Hydroptila poirrieri		X*				LDWF
	Hydroptila potosina [NT]					X	
	Hydroptila protera			**X**	X	X	
	Hydroptila quinola	X	**-X-**			X	
	Hydroptila remita	X	X			X	
	Hydroptila rono [NT]			X		X	
	Hydroptila sandersoni	X			X		
	Hydroptila scheiringi		**X**				
	Hydroptila scolops		**-X-**			X	
	Hydroptila spatulata	X			X*		
	Hydroptila strepha	X					
	Hydroptila tusculum		X				
	Hydroptila vala	X			X		
	Hydroptila virgata	X			X		
	Hydroptila wausbesiana	X	X		X	X	
	Hydroptila xera			X			
	Oxyethira abacatia					X	
	Oxyethira aculea [NT]			X	X	X	
	Oxyethira azteca [NT]				X	X	
	Oxyethira coercens	X			X	X	
	Oxyethira dualis	X		X	X	X	
	Oxyethira elerobi		X*			X	
	Oxyethira florida [NT]					X*	
	Oxyethira forcipata	X			X*	X*	
	Oxyethira glasa [NT]	X*	X		X*	X	
	Oxyethira grisea	**X**	X*				
	Oxyethira janella [NT]	X	X		X*	X	
	Oxyethira lumosa					X	

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Oxyethira maya [NT]					X	
	Oxyethira novasota	X	X			X	
	Oxyethira pallida	X	X		X	X	
	Oxyethira parce [NT]					X	
	Oxyethira pescadori	X*					
	Oxyethira rivicola	X					
	Oxyethira roberti					X	
	Oxyethira siminsigne		X				
	Oxyethira ulmeri [NT]					X	TPWD
	Oxyethira verna		X	**-X-**		X	
	Oxyethira zeronia	X	X		X	X	
	Paucicalcaria ozarkensis	X					ANHC
Subfamily Leucotrichiinae	*Alisotrichia arizonica*					X	
	Leucotrichia limpia [NT]					X	
	Leucotrichia pictipes			X*			
	Leucotrichia sarita [NT]					X	
	Zumatrichia notosa			X			
Subfamily Neotrichiinae	*Mayatrichia acuna*					X	
	Mayatrichia ayama [NT]	X			X	X	
	Mayatrichia ponta				X	X	
	Mayatrichia tuscaloosa					**X**	
	Neotrichia arkansasensis	X					
	Neotrichia armtagei					X	
	Neotrichia caxima [NT]					X	
	Neotrichia collata	X		**<u>X</u>**			
	Neotrichia edalis				X	X	
	Neotrichia juani					X	TPWD
	Neotrichia minutisimella	X	X		X	X	
	Neotrichia mobilensis					X	TPWD
	Neotrichia okopa	X			X	X	
	Neotrichia osmena					X	

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Neotrichia riegeli	X*			X*		
	Neotrichia sonora					X	TPWD
	Neotrichia vibrans [NT]	X			X	X	
Subfamily Ochrotrichiinae	*Metrichia nigritta* [NT]				X	X	
	Ochrotrichia anisca	X			X	X	
	Ochrotrichia argentea			X			
	Ochrotrichia arizonica			X		X	
	Ochrotrichia arva	X					
	Ochrotrichia boquillas					X	
	Ochrotrichia capitana					X	TPWD
	Ochrotrichia confusa					X	
	Ochrotrichia contorta	X*					ANHC
	Ochrotrichia dactylophora [NT]			X		X	
	Ochrotrichia eliaga	X			X		
	Ochrotrichia felipe					X	
	Ochrotrichia guadalupensis					X	TPWD
	Ochrotrichia ildria			**X**			
	Ochrotrichia logana			X		**X**	
	Ochrotrichia lometa			X			
	Ochrotrichia potomus				X*		
	Ochrotrichia riesi	X					
	Ochrotrichia robisoni	X			X		ANHC
	Ochrotrichia rothi					X	
	Ochrotrichia spinosa	X			X		
	Ochrotrichia spinulata			X		X	
	Ochrotrichia stylata [NT]			X	X	X	
	Ochrotrichia tarsalis [NT]	X	X*		X	X	
	Ochrotrichia weddleae	X			X		
	Ochrotrichia xena	X					
Subfamily Orthotrichiinae	*Ithytrichia clavata* [PL]	X*			X	X	
	Ithytrichia mazon	X			X		

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Ithytrichia mexicana [NT]			X			
	Orthotrichia aegerfasciella [NT]	X	X		X	X	
	Orthotrichia baldufi		**X**			X	
	Orthotrichia cristata [NT]	X	X		X	X	
	Orthotrichia curta	X*	X			X	
	Orthotrichia instabilis	X				X	
Subfamily Stacobiinae	*Stactobiella delira*	X			X		
	Stactobiella palmata	X			X		
Subfamily Uncertain	*Dibusa angata*	X			X		
Family **Ptilocolepidae**							
	Palaeagapetus celsus				X*		
Suborder Intergripalpia Infraorder Plenitentoria Superfamily PHRYGANEOIDEA Family **Leptostomatidae**							
Subfamily Lepidostomatinae	*Lepidostoma acarola*			X			
	Lepidostoma carrolli	X					
	Lepidostoma cascadense			X			
	Lepidostoma deceptivum			X*			
	Lepidostoma griseum	X					
	Lepidostoma knulli [NT]			X		X	
	Lepidostoma lescheni	X			X*		
	Lepidostoma liba	X					
	Lepidostoma morsei					X	USFW
	Lepidostoma ormeum			X*			
	Lepidostoma ozarkense	X			X		
	Lepidostoma pluviale [NT]			X			
	Lepidostoma roafi			X*			
	Lepidostoma togatum	X			X		
	Lepidostoma unicolor			X		**X**	
	Lepidostoma wigginsi		X				

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
Family **Brachycentridae**							
	Brachycentrus americanus PL			X		X	
	Brachycentrus lateralis	X*					
	Brachycentrus numerosus	X*	X			X	
	Brachycentrus occidentalis			X	X*		
	Micrasema bactro			X*			
	Micrasema ozarkana	X					
	Micrasema rusticum	X			X		
	Micrasema wataga	X	X		X*		
Family **Phryganeidae**							
Subfamily Phryganeinae	*Agrypnia vestita*	X	**X**		X	X	
	Agrypnia deflata			X			
	Banksiola crotchi			X*		**X**	
	Fabria inornata		**X**				
	Phryganea sayi	X					
	Ptilostomis ocellifera	X	X		X	X	
	Ptilostomis postica	X	X		X	X	
	Ptilostomis semifasciata					X*	
Superfamily LIMNEPHILOIDEA Family **Apataniidae**							
	Apatania sp.			**X**			
Family **Limnephilidae**							
Subfamily Dicosmoecinae	*Amphicosmoecus canax*			X*			
	Dicosmoecus atripes			X			
	Ecclisomyia conspersa PL			X			
	Ironoquia kaskaskia	X	X				
	Ironoquia punctatissima	X	X		X	X	
	Onocosmoecus unicolor PL			X			
Subfamily Limnephilinae Tribe Chilostigmini	*Frenesia missa*	X					
	Homophylax adriana			X*			

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Psychoglypha subborealis			X			
Tribe Hesperophylacini	*Crenophylax sperryi*			X			
	Psychoronia brooksi			X			
	Psychoronia costalis			X			
Tribe Limnephilini	*Anabolia bimaculata*			X			
	Clistoronia formosa			X*			
	Clistoronia maculata			X			
	Clistoronia magnifica			X*			
	Hesperophylax consimilis					X	
	Hesperophylax designatus			X			
	Hesperophylax magnus NT			X			
	Hesperophylax occidentalis			X		X	
	Limnephilus acnestus			**X**			
	Limnephilus adapus					X	TPWD
	Limnephilus apache			X			
	Limnephilus castor			X			
	Limnephilus chavas			X			
	Limnephilus cockerelli			X			
	Limnephilus diversus			X			
	Limnephilus frijole NT			X		X	
	Limnephilus lithus			X		X	
	Limnephilus moestus			X			
	Limnephilus rohweri			X			
	Limnephilus secludens			X*			
	Limnephilus spinatus			**X**			
	Limnephilus submonilifer	X*				**X**	
	Limnephilus taloga			X	X	X	
	Limnephilus tulatus NT			X			
	Platycentropus amicus		X*				
	Platycentropus radiatus	X				**X**	
Tribe Stenophylacini	*Chyranda centralis*			X*			

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Pycnopsyche antica		X*			X	
	Pycnopsyche guttifer	X	X*				
	Pycnopsyche indiana	X	X*			X	
	Pycnopsyche lepida	X	X		X	X	
	Pycnopsyche rossi	X					
	Pyncopsyche scabripennis	X*	X*				
	Pycnopsyche subfasciata	X			X		
Family **Thremmatidae**							
	Neophylax concinnus	X					
	Neophylax fuscus	X*					
	Neophylax oligius			**X**			
	Oligophlebodes minutus			X			
	Oligophlebodes sigma			X*			
Infraorder Brevitentoria Superfamily LEPTOCEROIDEA Family **Odontoceridae**							
Subfamily Odontocerinae	*Marilia flexuosa* [NT]	X		X	X	X	
	Marilia mexicana [NT]			**X**			
	Marilia nobsca [NT]			**X**		X	
Family **Leptoceridae**							
Subfamily Leptocerinae Tribe Athripsodini	*Ceraclea ancylus*	X			X		
	Ceraclea cancellata	X	X		X		
	Ceraclea diluta	X*	X*				
	Ceraclea enodis	X*					
	Ceraclea flava	X			X	X	
	Ceraclea maculata	X	X		X	X	
	Ceraclea neffi	**X**					
	Ceraclea nepha	X			X	X	
	Ceraclea ophioderus	X	X			X	
	Ceraclea protonepha	**X**	X		**X**	X	

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Ceraclea punctata	X	**X**		X		
	Ceraclea resurgens		X		X		
	Ceraclea spongillovorax		X				LDWF
	Ceraclea tarsipunctata	X	X		X	X	
	Ceraclea transversa	X	X		X	X	
Tribe Leptocerini	*Leptocerus americanus*	X	X		X	X	
Tribe Mystacidini	*Mystacides sepulchralis*	X			X		
Tribe Nectopsychini	*Nectopsyche albida*					X	
	Nectopsyche candida	X	X		X	X	
	Nectopsyche diarina	**X**			X	X	
	Nectopsyche exquisita	X	**X**		X	X	
	Nectopsyche gracilis [NT]			X*	**-X-**	X	
	Nectopsyche pavida [NT]	X	X		X	X	
	Nectopsyche spiloma	X	X		X	X	
	Nectopsyche stigmatica [NT]			X		**X**	
	Nectopsyche texana					X	TPWD
Tribe Oecetini	*Oecetis arizonica* [NT]			**X**			
	Oecetis avara [NT]	X	**X**	X	X	X	
	Oecetis cinerascens [NT]	X	X		X	X	
	Oecetis disjuncta [NT]			X		**X**	
	Oecetis ditissa	X	X		X	X	
	Oecetis eddlestoni	X			X		
	Oecetis georgia		X			X	
	Oecetis inconspicua [NT]	X	X	X	X	X	
	Oecetis morsei		**X**				
	Oecetis nocturna	X	X		X	X	
	Oecetis ochracea [PL]					**X**	
	Oecetis osteni	X	X		X*	X	
	Oecetis ouachita	X			X		
	Oecetis ozarkensis	X					
	Oecetis persimilis	X	X		X	X	

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Oecetis scala	X					
	Oecetis sphyra		X			X	
Tribe Setodini	*Setodes dixiensis*		X				
	Setodes oxapius	X			X		
Tribe Triaenodini	*Triaenodes aba*	X	X*				
	Triaenodes cumberlandensis	X*			X		
	Triaenodes dipsius	X			X		
	Triaenodes frontalis [NT]			X	X		
	Triaenodes helo				X		
	Triaenodes ignitus	X	X		X	X	
	Triaenodes injustus	X			X	X	
	Triaenodes marginatus	X			X	X	
	Triaenodes ochraceus	X	**X**			X	
	Triaenodes perna	X	X		X	X	
	Triaenodes reuteri [PL]			X			
	Triaenodes smithi	X*	X			X	
	Triaenodes tardus [NT]	X			X	X	
	Triaenodes tridontus				X		
Family **Calamoceratidae**							
Subfamily Calamoceratinae	*Anisocentropus pyraloides*		**X**				
	Phylloicus aeneus [NT]			X		X	
	Phylloicus mexicanus [NT]					**X**	
Family **Molannidae**							
	Molanna blenda	X	X				
	Molanna cinerea				X*		
	Molanna tryphena		X			X	
	Molanna ulmerina	X	X		X	X	
	Molanna uniophila	X			X		
Superfamily SERCOSTOMATOIDEA Family **Helicopsychidae**							
	Helicopsyche borealis [NT]	X		X	X	X	

Higher Classification	Species	AR	LA	NM	OK	TX	Agency
	Helicopsyche limnella	X			X		
	Helicopsyche mexicana [NT]			X		X	
	Helicopsyche paralimnella	**X**					USFW
	Helicopsyche piroa [NT]	X	X		X	X	
	Helicopsyche vergelana [NT]		**X**				
Family **Sericostomatidae**							
	Agarodes crassicornis		X*			X	
	Agarodes distinctus		**X**				
	Agarodes libalis		X			X	LDWF
	Gumaga griseola [NT]			X			

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APPENDIX C

EXPANDED SPECIES RANGE

US state and Canadian province and territory abbreviations given at end of table.

Family	Species	AR	LA	NM	OK	TX	Distribution
Calamoceratidae	*Anisocentropus pyraloides*		LSAM INHS				AL, FL, GA, DE, KY, MS, NC, NJ, SC, TN, VA
	Phylloicus mexicanus					DER	AZ, Mexico
Glossosomatidae	*Agapetus minutus*			INHS			DE, KY, MA, NC, NY, ON, PA, TN, VA, WV
	Culoptila cantha				INHS		AZ, CO, ID, MD, ME, MT, NM, NV, SK, TX, UT, VA, WA, WY
Helicopsychidae	*Helicopsyche paralimnella*	EFNHM INHS					NC, SC
	Helicopsyche vergelana		INHS				Mexico, Central America
Hydropsychidae	*Cheumatopsyche analis*			DER			AB, AL, AR, BC, CO, CT, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MB, MD, ME, MI, MN, MO, MS, MT, NB, NC, ND, NE, NF, NH, NJ, NS, NV, NY, OH, OK, ON, OR, PA, PE, QC, SC, SD, SK, TN, TX, UT, VA,

Family	Species	AR	LA	NM	OK	TX	Distribution
							VT, WA, WI, WV, WY
	Cheumatopsyche aphanta		HAP				AR, IL, IN, KS, KY, ME, MI, MN, MO, NB, ND, NH, NY, OH, OK, PA, QC, TN, TX, VT, WI
	Cheumatopsyche harwoodi	DER			DER		AB, AL, CT, GA, IN, KY, MB, ME, NB, NC, NS, NY, OH, ON, PA, PE, RI, SC, TN, VA, WV
	Cheumatopsyche oxa					EFMHM	AB, AL, AR, BC, CT, GA, IL, IN, KS, KY, MB, ME, MI, MN, MO, MS, MT, NB, NC, NH, NY, OH, OK, ON, PA, QC, SC, SD, SK, TN, VA, VT, WI, WV, WY
	Diplectrona metaqui		INHS				AL, CT, GA, IL, IN, KY, MO, NC, OH, PA, SC, TN, VA, WV

Family	Species	AR	LA	NM	OK	TX	Distribution
	Diplectrona modesta		CLM INHS LSAM				AL, AR, CT, DE, FL, GA, IL, IN, KS, KY, MA, MD, ME, MI, MN, MO, MS, NC, NF, NH, NS, NY, OH, OK, ON, PA, QC, SC, SD, TN, TX, VA, VT, WI, WV
	Hydropsyche alvata					TXAM	AL, AR, FL, GA, IA, IL, IN, KY, LA, MI, MO, MS, NC, OK, VA
	Hydropsyche bronta			DER			AB, AR, CO, CT, DE, IA, IL, IN, KY, MA, MB, MD, MI, MN, MO, ME, MT, NB, NC, ND, NE, NH, NS, NY, OH, OK, ON, PA, QC, SC, SK, TN, VA, VT, WI, WV, WY
	Hydropsyche carolina					SRM	GA, NC, SC, TN
	Hydropsyche incommoda				CLM INHS	DER INHS	AL, AR, CO, FL, GA, IA, IL, KS, KY, LA, MD, MI,

Family	Species	AR	LA	NM	OK	TX	Distribution
							NC, NE, NY, OH, QC, SC, VA
	Hydropsyche orris			DER			AL, AR, FL, GA, IA, IL, IN, KS, KY, LA, MI, MN, MO, MS, NC, NE, NY, OH, OK, PA, SK, TN, TX, WI, WV
	Hydropsyche placoda	INHS	CLM				AB, IA, IL, IN, MB, MN, MT, NY, OH, ON, PA, QC, SD, SK, TN, WI
	Hydropsyche sparna		LSAM				AL, CT, DE, GA, IL, IN, KS, KY, LB, MA, MB, MD, ME, MI, MN, MS, NB, NC, NF, NH, NJ, NS, NY, OH, ON, PA, PE, QC, SC, TN, VA, VT, WI, WV
	Hydropsyche tana			DER			BC, CA, ID, MT, NV, OR
	Marcrostemum zebratum	INHS					AL, CT, DC, DE, GA, IA, IL, IN, KY, MA, MD, ME, MI, MN,

Family	Species	AR	LA	NM	OK	TX	Distribution
							MO, NC, ND, NH, NJ, NY, OH, ON, PA, QC, SC, TN, UT, VA, VT, WI, WV
	Smicridea dispar					INHS	AZ, CA, UT, Mexico
Hydroptilidae	*Hydroptila ajax*		HAP				AZ, CA, CO, FL, IA, ID, IL, IN, KS, KY, MB, MN, MO, MT, NE, NV, NY, OH, OK, OR, PA, TX, UT, VA, WA, WI, WV, WY, Mexico
	Hydroptila amoena		CLM				AL, AR, IL, IN, KY, MI, MN, MO, NH, OH, OK, PA, QC, SC, TN, VA, WI
	Hydroptila consimilis		CLM				AB, AL, AR, AZ, BC, CO, CT, DE, IA, ID, IL, IN, KS, KY, MB, ME, MI, MN, MO, MT, NB, ND, NH, NM, NT, NV, NY, OH, OK, ON, OR, PA, QC,

Family	Species	AR	LA	NM	OK	TX	Distribution
							SC, TN, TX, UT, VA, VT, WA, WI, WY
	Hydroptila maculata		CLM				DC, FL, ME, NC, NH, VA
	Hydroptila mexicana	INHS					Mexico
	Hydroptila novicola	UAR					AL, FL, GA, LA, ME, MN, MS, NH, NY, QC, TX
	Hydroptila pecos				CSU DER		AZ, CO, KS, MT, NE, NM, SD, TX, WY
	Hydroptila protera			EFNHM			OK, TX
	Hydroptila quinola		LSAM HAP				AL, AR, CT, FL, GA, KY, ME, MN, MS, NC, NH, ON, PA, QC, SC, TN, TX, VA
	Hydroptila scolops		HAP				IL, KS, KY, MB, MN, MO, TX, WI
	*Neotrichia collata**			INHS			AL, AR, IL, KY, ME, NY, SC, UT, VT
	Ochrotrichia logana					DER	AK, AZ, CA, CO, ID, NM, OR, UT, WY
	Orthotrichia baldufi		CLM				AL, FL, ME, MI, MN, NH, NY, QC, TX, WI
Lepidostomatidae	*Lepidostoma unicolor*					INHS	AB, AZ, BC, CA, CO, ID, MB,

Family	Species	AR	LA	NM	OK	TX	Distribution
							MN, MT, ND, NM, NV, OR, QC, SK, SK, UT, WA, WY, YT
Leptoceridae	*Ceraclea neffi*	CLM					AL, KS, KY, MI, MN, NC, OH, TN, VA, WV
	Ceraclea protonepha	CLM DER INHS SRM			CLM EFNHM		AL, DE, FL, GA, KS, KY, LA, MS, NC, OH, SC, TN, TX, VA
	Ceraclea punctata		EFNHM				AR, DC, IL, IN, KS, KY, MD, ME, MI, MO, NC, NH, NY, OH, OK, PA, QC, TN, VA, WI
	Nectopsyche diarina	SRM					CO, DE, ID, IL, IN, KS, MB, MI, MO, MT, ND, NE, NY, OH, OK, ON, SD, SK, TX, UT, VA, VT, WI, WY
	Nectopsyche exquista		GBIF LSAM				AL, AR, CT, DC, DE, FL, GA, IL, IN, KS, KY, MA, MB, MD, ME, MI, MN, MO, MS, NB, NC, ND, NE, NH,

Family	Species	AR	LA	NM	OK	TX	Distribution
							NJ, NS, NY, OH, OK, ON, PA, QC, SC, TN, TX, VA, VT, WI, WV
	Nectopsyche gracilis				HAP		AZ, CA, CO, NM, NV, OR, SK, TX, UT, WA, Mexico
	Nectopsyche stigmatica					DER INHS	AZ. CO, NE, NM, WY, Mexico
	Oecetis arizonica			GBIF			AZ, CO, Mexico
	Oecetis avara		LSAM				AL, AR, AZ, BC, CA, CO, CT, DC, DE, FL, GA, IA, ID, IL, IN, KS, KY, MA, MB, MD, ME, MI, MN, MO, MS, MT, NC, ND, NH, NJ, NM, NS, NV, NY, OH, OK, ON, OR, PA, QC, SC, SK, TN, TX, UT, VA, VT, WA, WI, WV, Mexico, Central America, South America

Family	Species	AR	LA	NM	OK	TX	Distribution
	Oecetis disjuncta					SRM	CA, OR
	Oecetis morsei		INHS				AL, FL, SC
	Oecetis ochracea					DER	AB, AK, BC, CA, CO, IN, MB, MN, MT, NC, ND, NT, OH, ON, SD, SK, TN, VA, WI, WY, YT, Paleartic
	Triaenodes ochraceus		UMSP				AL, AR, CT, DE, FL, GA, KY, MA, MD, ME, MS, NC, NJ, OH, SC, TN, TX, VA
Limnephilidae	*Limnephilus acnestus*			DER			AZ, CA, CO, UT
	Limnephilus spinatus			INHS			AB, AZ, BC, CA, CO, ID, MT, NV, OR, UT, WA, WY
	Limnephilus submonilifer					UMSP	AR, CO, CT, DC, DE, IA, IL, IN, KY, MA, MB, MD, M, MI, MN, NC, ND, NF, NJ, NS, NY, OH, ON, PA, QC, RI, SC, SD, TN, VA, VT, WA, WI, WV

Family	Species	AR	LA	NM	OK	TX	Distribution
	Platycentropus radiatus					DER	AL, AR, CT, DE, GA, IA, IL, IN, KY, MA, MB, MD, ME, MI, MN, MS, NC, ND, NF, NH, NJ, NS, NT, NY, OH, ON, PA, QC, SC, TN, VA, WA, WI, WV
Odontoceridae	*Marilia mexicana*			GBIF			Mexico
	Marilia nobsca			DER			AZ. TX, Mexico
Philopotamidae	*Chimarra angustipennis*			DER			AR, AZ, CA, MT, NV, OK, OR, TX, Mexico, Central America
	Chimarra obscura		INHS LSAM				AL, AR, CT, DE, FL, GA, IL, IN, KS, KY, LB, MA, MB, MD, ME, MI, MN, MO, MS, NC, NE, NF, NH, NJ, NS, NY, OH, OK, ON, PA, QC, SC, TN, TX, VA, VT, WI, WV
	Chimarra socia					SRM	AL, AR, CT, DC, FL, GA, IN, KY, LA, LB, MA, MB, MD, ME,

Family	Species	AR	LA	NM	OK	TX	Distribution
							MI, MN, MO, MS, NB, NC, NF, NH, NJ, NS, NY, OH, ON, PA, QC, SC, TN, VA, VT, WI, WV
	Dolophilodes novusamericanus			DER			AZ, BC, CA, ID, MT, NV, OR, UT, WA, WY
	Wormaldia arizonensis			EFNHM			AZ, NV, TX, UT, Mexico
	Wormaldia gabriella			EFNHM			AB, BC, CA, CO, ID, MB, MT, NT, NV, OR, QC, SD, UT, WA, WY, YT
Phryganeidae	*Agrypnia vestita*		LSAM				AB, AL, AR, BC, CT, DC, DE, FL, GA, IL, IN, KS, KY, LB, MA, MB, MD, ME, MI, MN, MO, MS, MT, NB, NC, ND, NE, NF, NH, NJ, NS, NT, OH, OK, ON, OR, PA, QC, SC, TN, TX, VA, VT, WA, WI, WV

Family	Species	AR	LA	NM	OK	TX	Distribution
	Banksiola crotchi					INHS	AB, AK, BC, CA, CT, IL, IN, LB, MA, MB, ME, MI, MN, MT, NB, ND, NF, NH, NJ, NM, NS, NT, NY, OH, ON, OR, PA, PE, QC, SK, UT, VT, WA, WI, WV, YT
	Fabria inornata		INHS				AB, IA, IL, IN, MB, MI, MN, NE, NT, ON, QC, WI, WV
Polycentropodidae	*Cernotina astera*			HAP			TX, Mexico
	Cernotina calcea			HAP			AL, AR, FL, IL, IN, KS, KY, LA, MO, MS, NC, OK, TN, TX, VA, Mexico, Nicaragua
	Cernotina oklahoma			INHS			OH, OK, TX
	Cyrnellus fraternus			HAP			AL, AR, CO, DE, FL, GA, IA, IL, IN, KA, KY, LA, MD, ME, MI, MN, MO, MS, NC, NE, NY, OH, OK, PA, SC, TN, TX, VA,

Family	Species	AR	LA	NM	OK	TX	Distribution
							WI, WV, Mexico, Central America, South America
	Holocentropus picicornis				INHS		AB, MB, MN, NH, NT, SK, Palearctic
	Nyctiophylax neotropicalis	INHS					Columbia
	Nyctiophylax serratus		UMSP				AL, AR, FL, KY, MO, MS, OK, TN, TX, VA
	Nyctiophylax vestitus	INHS					DC
	Plectrocnemia remota	CLM UAR					AB, AK, BC, CT, DE, IL, IN, KY, MA, MB, ME, MI, MN, MT, NF, NH, NY, OH, ON, PA, QC, SK, WA, WI, YT
	Polycentropus gertschi			CSU DER EFNHM INHS			AZ, CO, TX
Psychomyiidae	*Psychomyia flavida*			INHS LSAM			AB, AL, AR, AZ, BC, CA, CO, CT, DC, DE, FL, ID, IL, IN, KS, KY, MA, MB, MD, ME, MI, MN, MO, MT,

Family	Species	AR	LA	NM	OK	TX	Distribution
							NB, NC, ND, NH, NJ, NS, NY, OH, OK, ON, OR, PA, QC, SC, SD, SK, TN, UT, VA, VT, WA, WI, WV, WY, Siberia, Mongolia
Rhyacophilidae	*Rhyacophila vofixa*			INHS			AB, AK, BC, CO, ID, UT, WA, WY, YT
Sericostomatidae	*Agarodes distinctus*		UMSP				CT, GA, MA, ME, MI, MN, NH, NY, ON, QC, SC, TN, WI
Thremmatidae	*Neophylax oligius*			INHS			AL, CT, DE, GA, MA, MD, ME, MI, MN, MS, NC, NF, NH, NJ, NS, NY, OH, ON, PA, QC, SC, TN, VA, VT, WI, WV

* According to Rasmussen and Morse (2016) all the specimens related to the distributions published for this species need to be compared to *N. doppelganger*

US State and Canadian Province and Territory Abbreviations

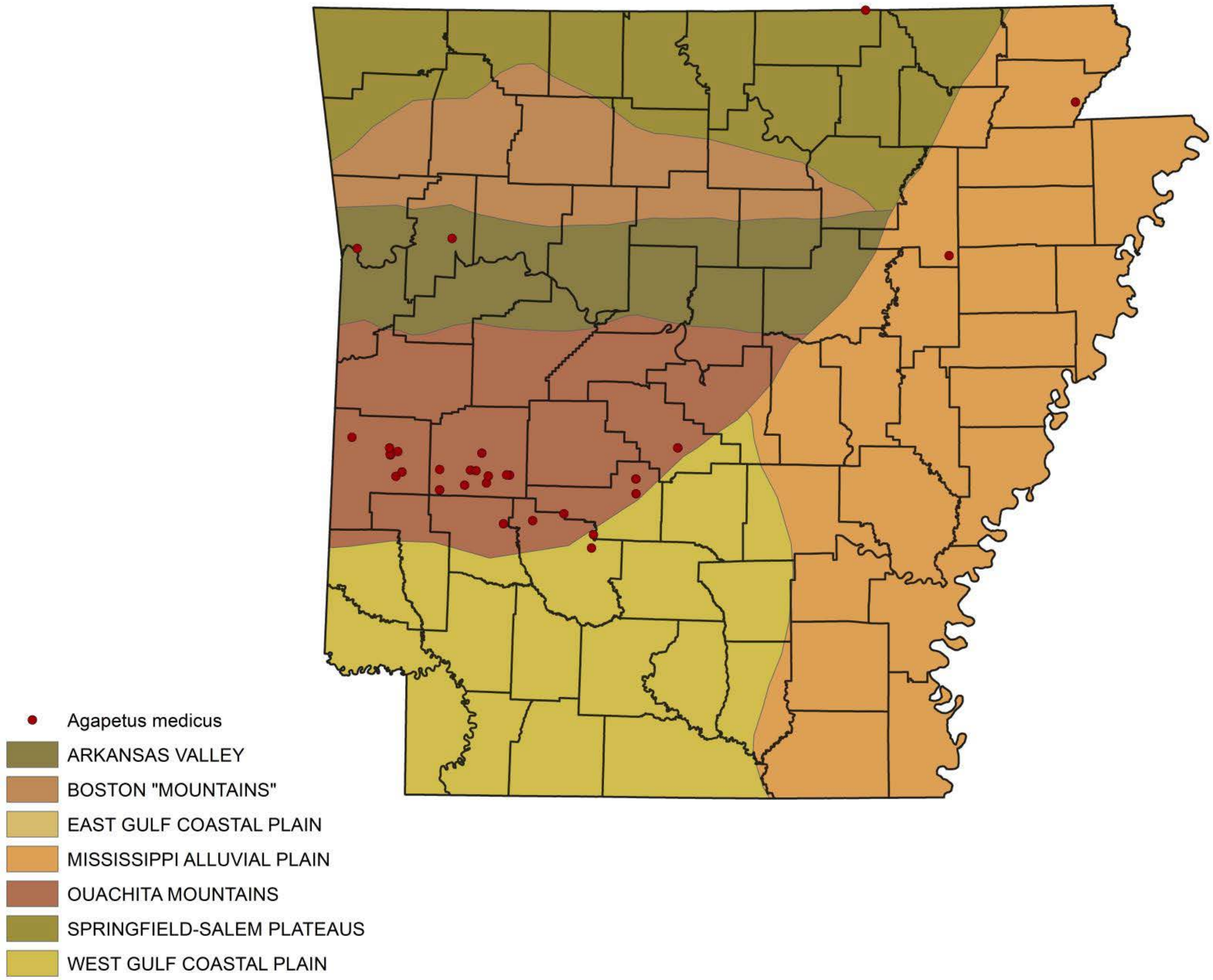
US State	Abbr	US State	Abbr	US State	Abbr	US State	Abbr
Alabama	AL	Indiana	IN	Nevada	NV	Tennessee	TN
Alaska	AK	Iowa	IA	New Hampshire	NH	Texas	TX
Arizona	AZ	Kansas	KS	New Jersey	NJ	Utah	UT
Arkansas	AR	Kentucky	KY	New Mexico	NM	Vermont	VT
California	CA	Louisiana	LA	New York	NY	Virginia	VA
Colorado	CO	Maine	ME	North Carolina	NC	Washington	WA
Connecticut	CT	Maryland	MD	North Dakota	ND	West Virginia	WV
Delaware	DE	Massachusetts	MA	Ohio	OH	Wisconsin	Wi
District of Columbia	DC	Michigan	MI	Oklahoma	OK	Wyoming	WY
Florida	FL	Minnesota	MN	Oregon	OR		
Georgia	GA	Mississippi	MS	Pennsylvania	PA		
Hawaii	HI	Missouri	MO	Rhode Island	RI		
Idaho	ID	Montana	MT	South Carolina	SC		
Illinois	IL	Nebraska	NE	South Dakota	SD		

Can Province/Territory	Abbr	Can Province/Territory	Abbr
Alberta	AB	Ontario	ON
British Columbia	BC	Prince Edward Island	PE
Manitoba	MB	Quebec	QC
Newfoundland & Labrador	NF & LB	Saskatchewan	SK
Northwest Territories (including Nunavut)	NT	Yukon	YT
Nova Scotia	NS		

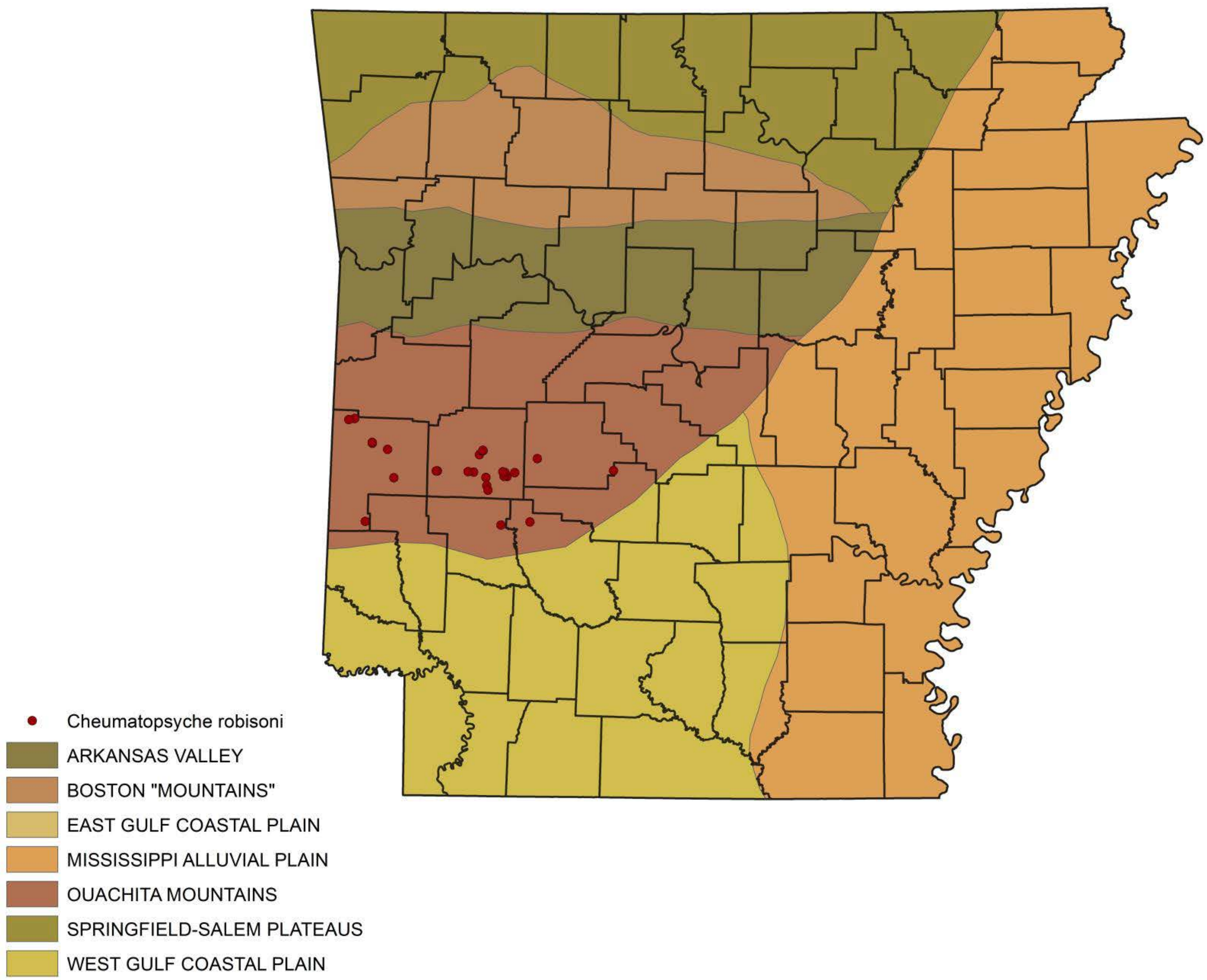
APPENDIX D

STATE MAPS FOR ENDEMIC SPECIES BY PHYSIOGRAPHIC SECTION

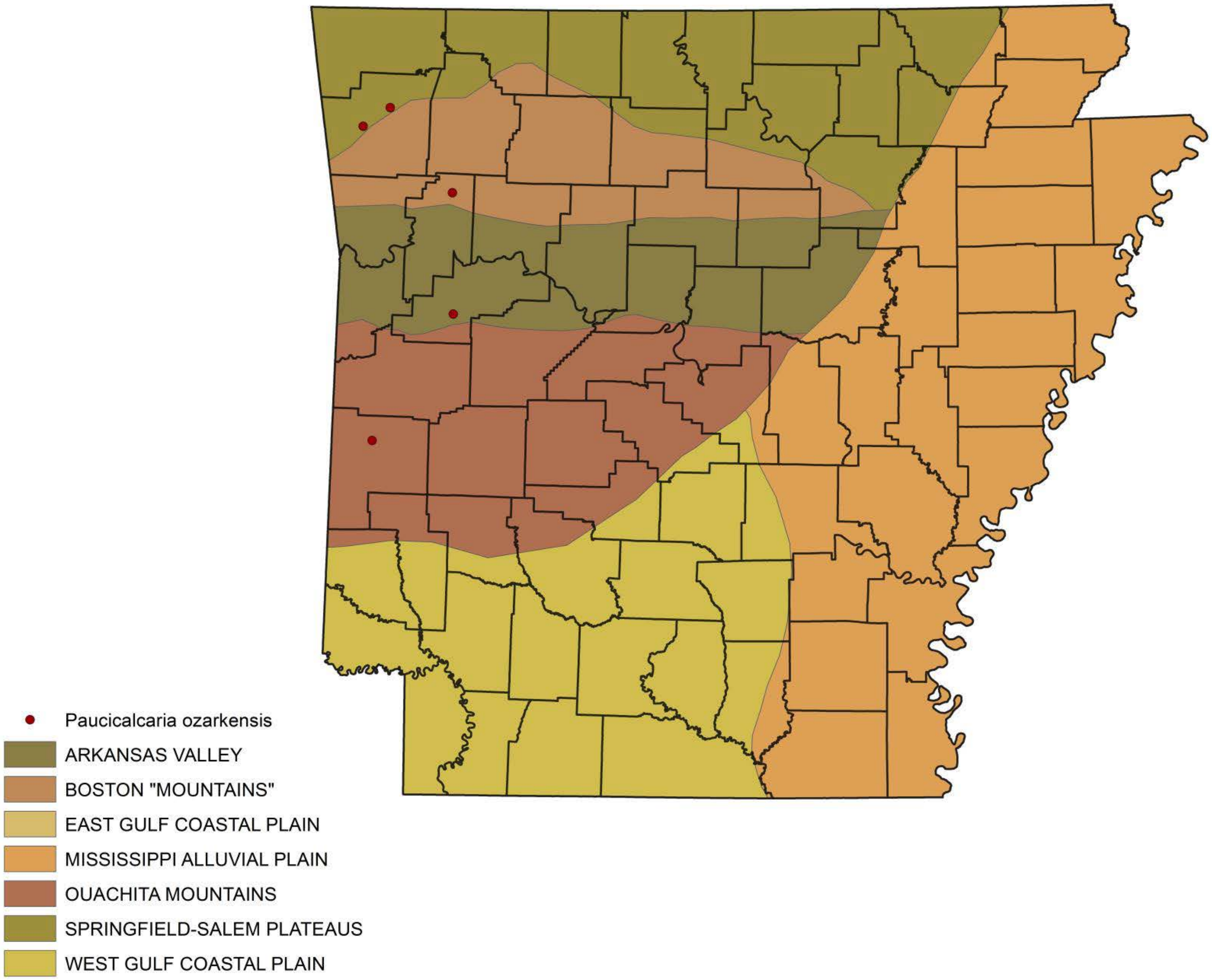
Arkansas endemic *Agapetus medicus* (Glossossomatide) by physiographic section (physiographic provinces: Coastal Plain, Ouachita and Ozark Plateaus).



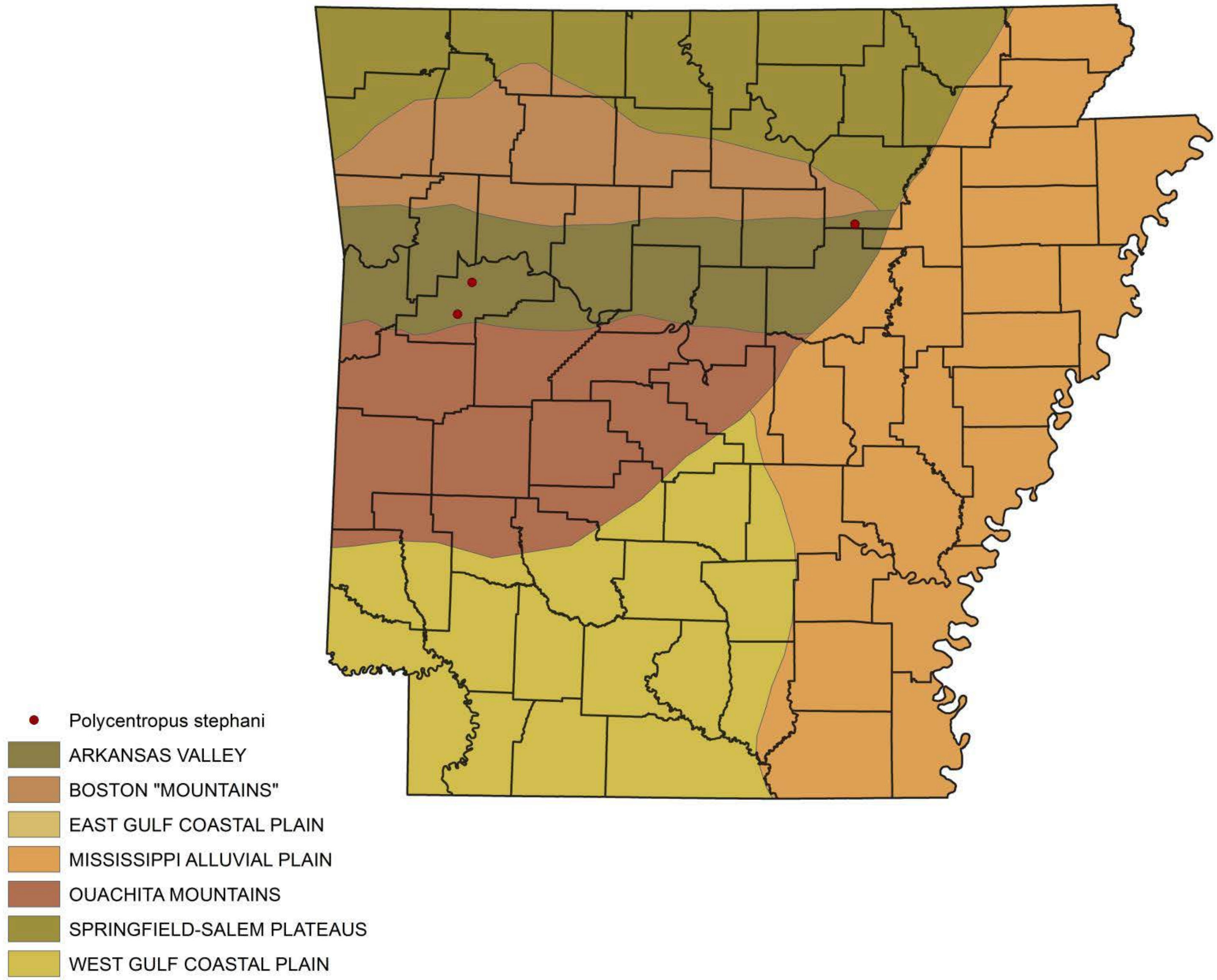
Arkansas endemic *Cheumatopsyche robisoni* (Hydropsychidae) by physiographic section (physiographic province: Ouachita).



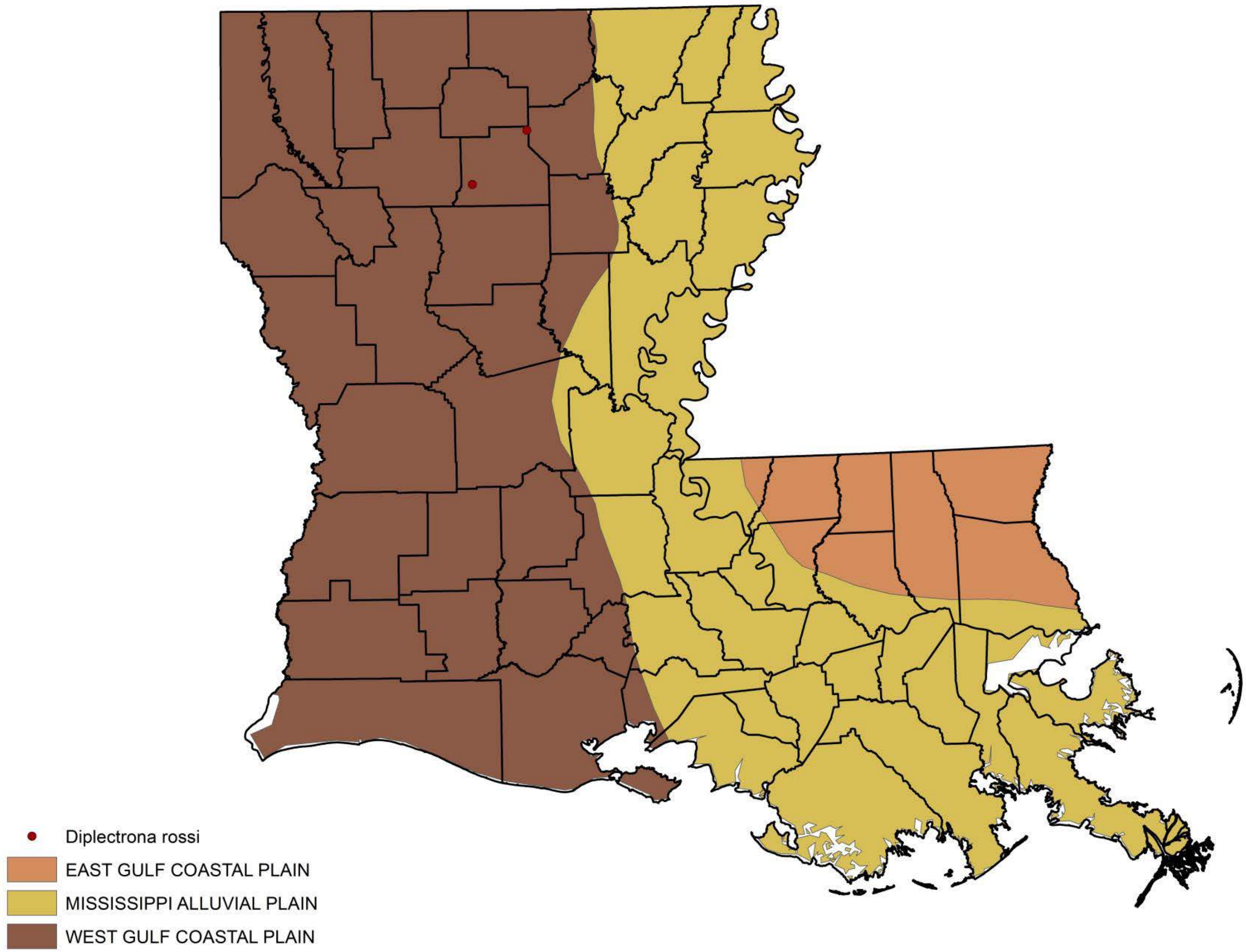
Arkansas endemic *Paucicalcaria ozarkensis* (Hydroptilidae) by physiographic section (physiographic provinces: Ozarks Plateaus and Ouachita)



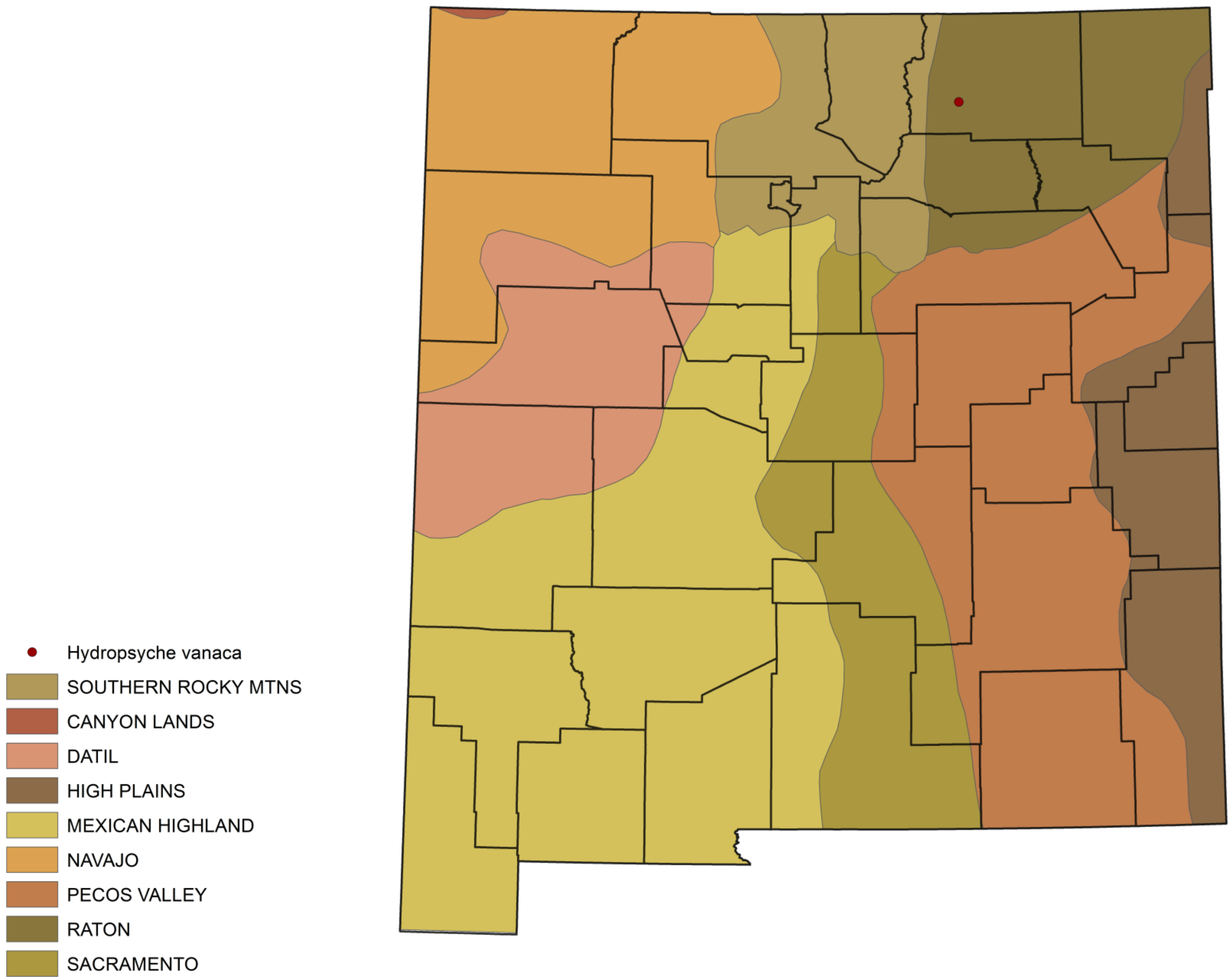
Arkansas endemic *Polycentropus stephani* (Polycentropodidae) by physiographic section (physiographic provinces: Ozark Plateaus and Ouachita).



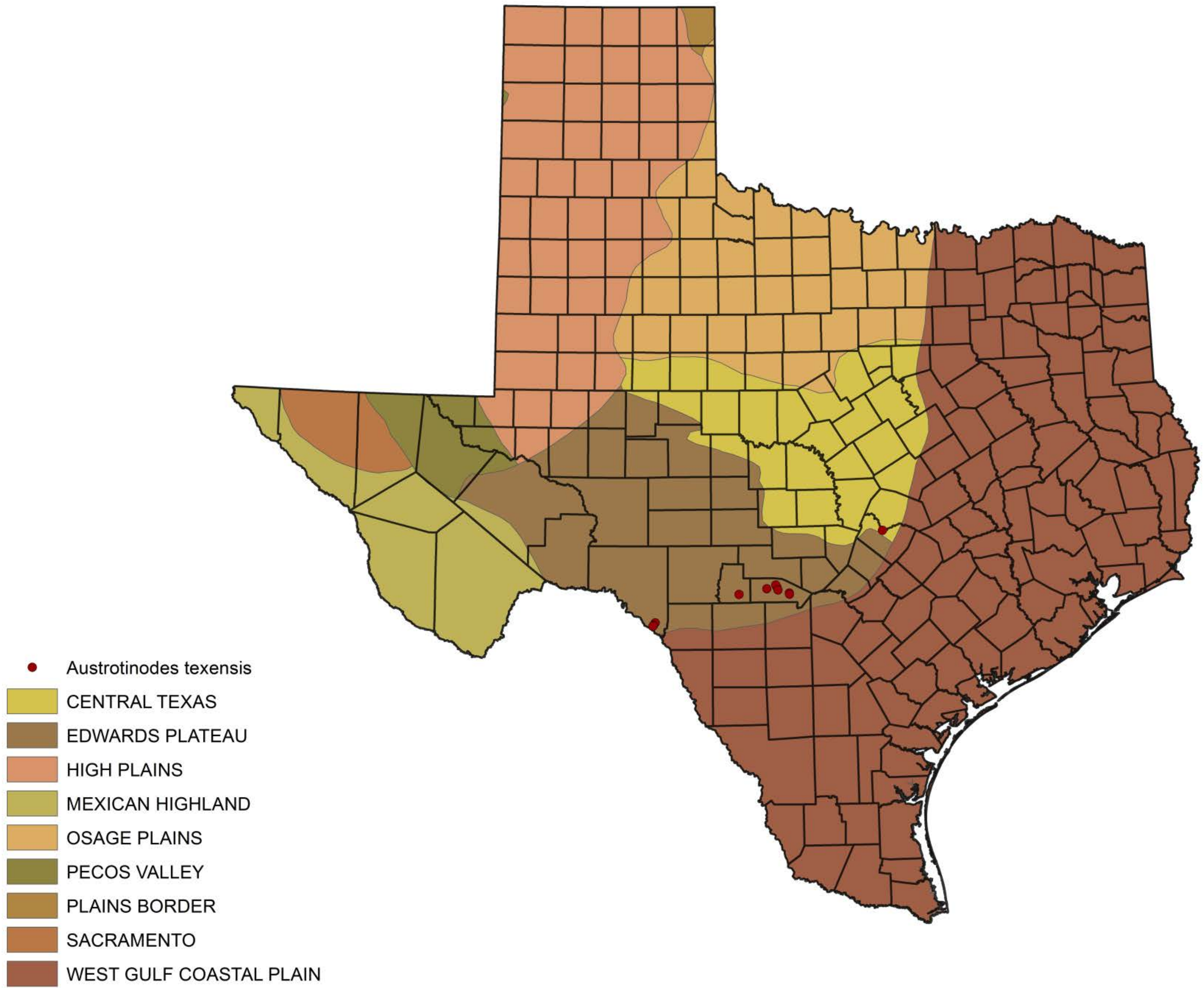
Louisiana endemic *Diplectrona rossi* (Hydropsychidae) by physiographic section (physiographic province: Coastal Plain).



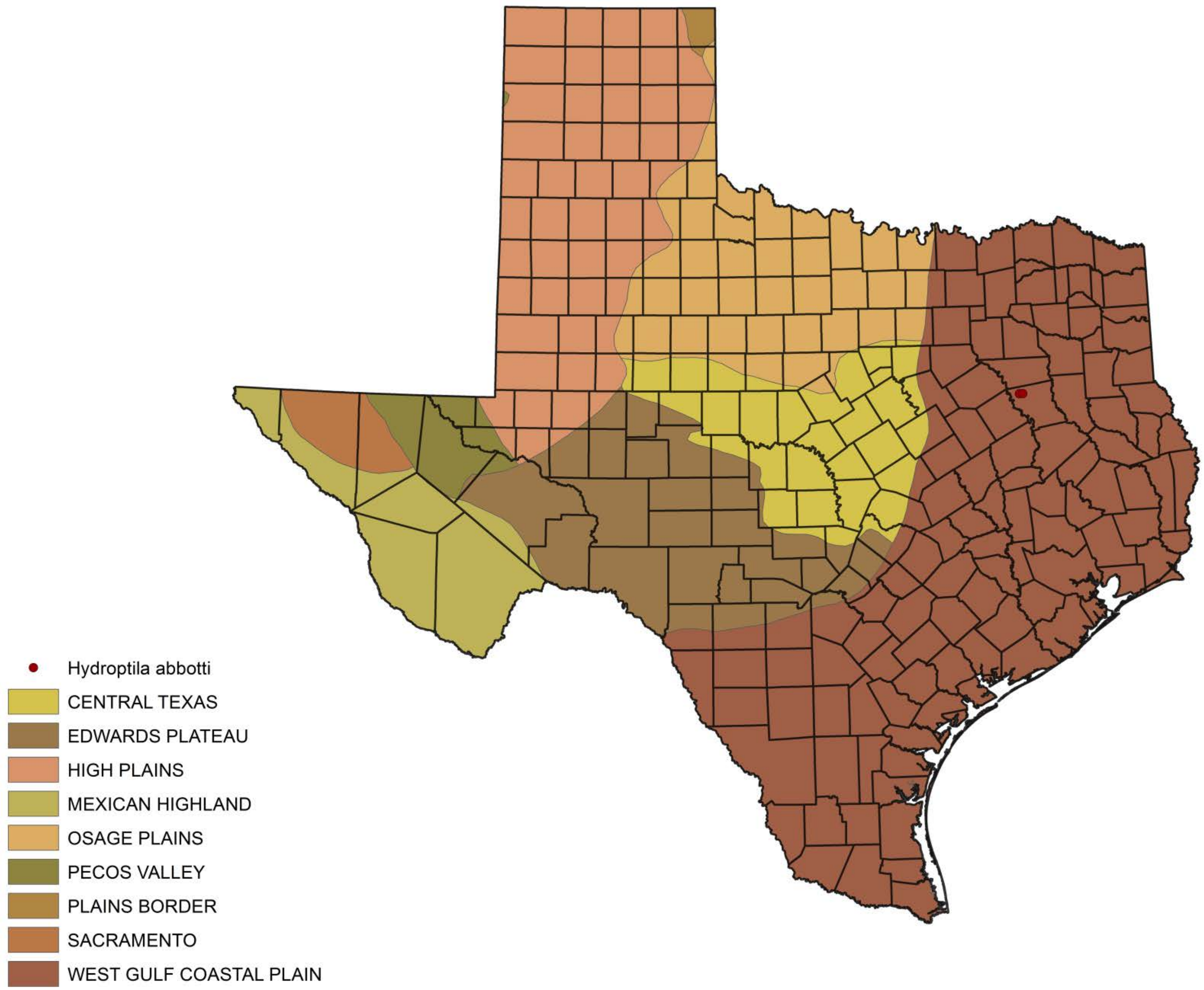
New Mexico endemic *Hydropsyche vanaca* (Hydropsychidae) by physiographic section (physiographic province: Great Plains).



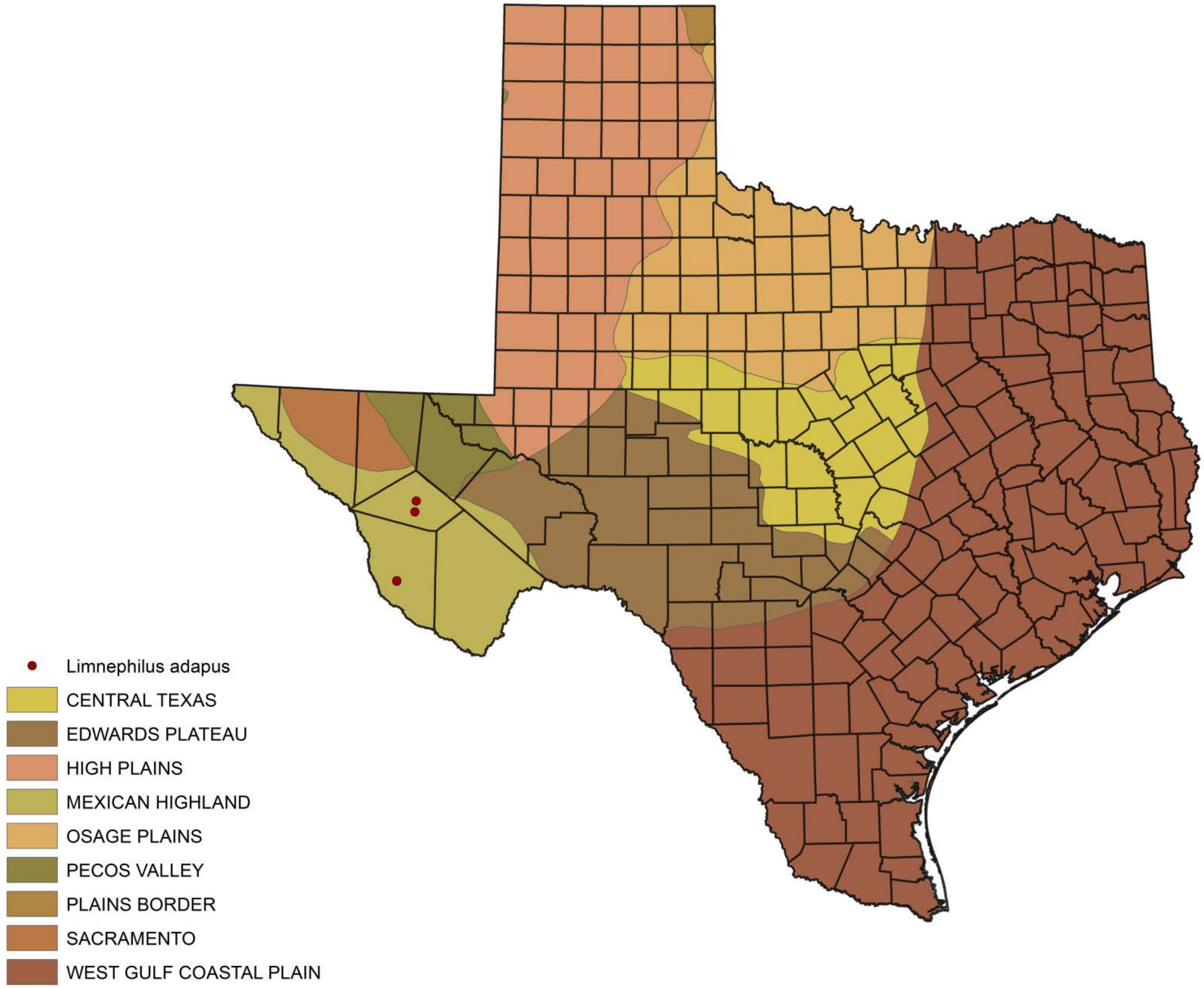
Texas endemic *Austrotinodes texensis* (Ecnomidae) by physiographic section (physiographic province: Great Plains).



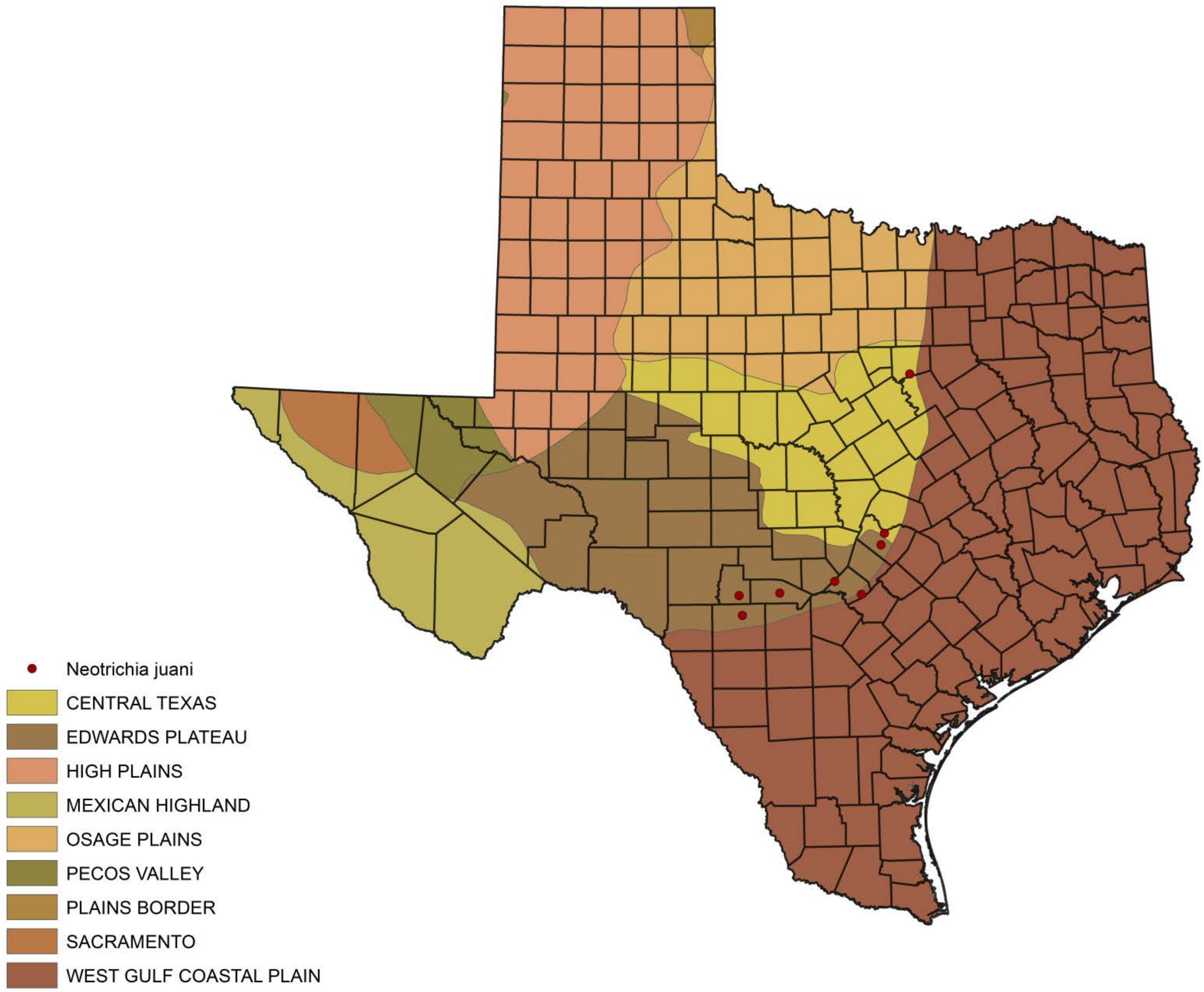
Texas endemic *Hydroptila abbotti* (Hydroptilidae) by physiographic sections (physiographic province: Coastal Plains).



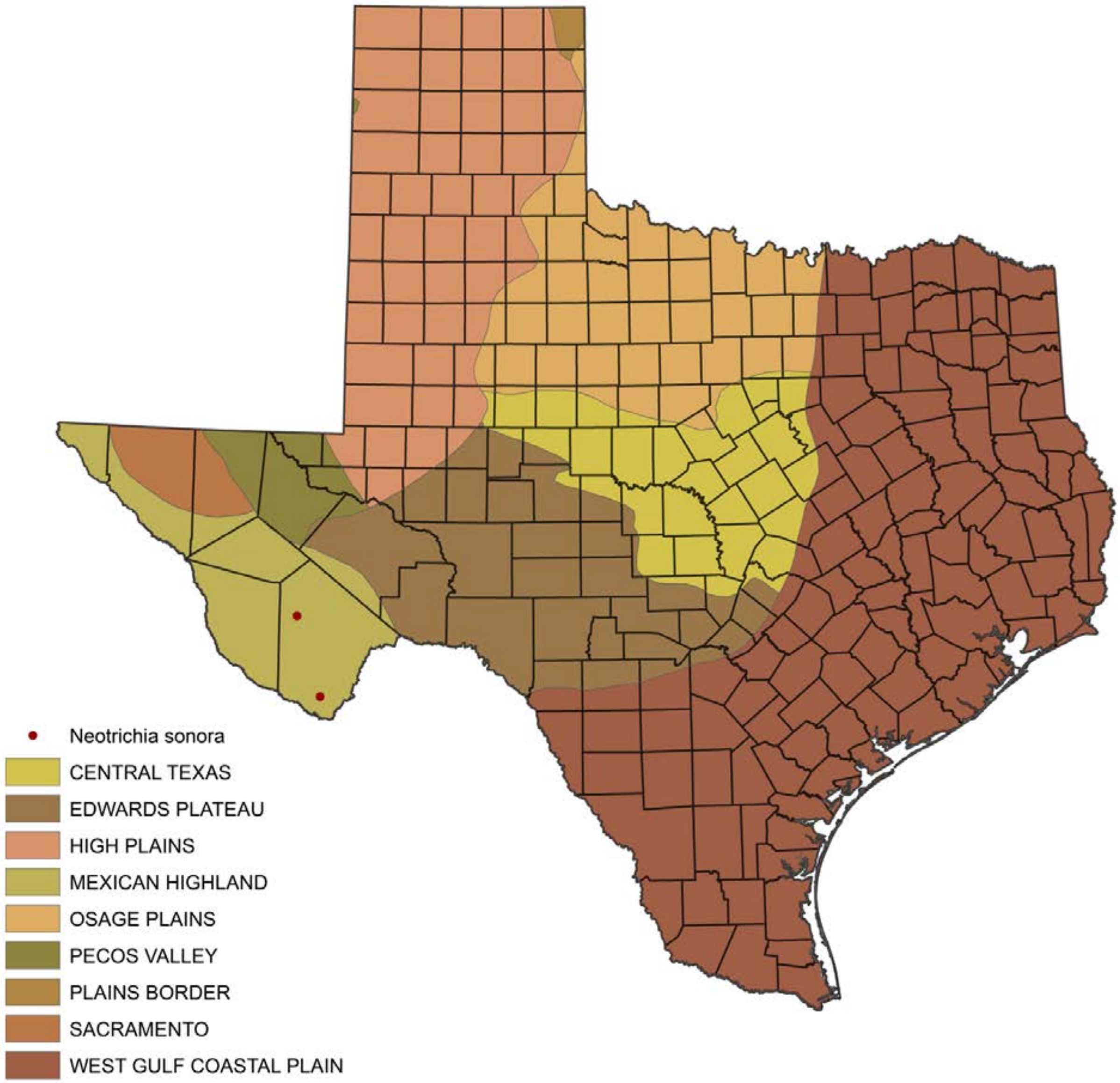
Texas endemic *Limnephilus adapus* (Limnephilidae) by physiographic section (physiographic province: Basin and Range).



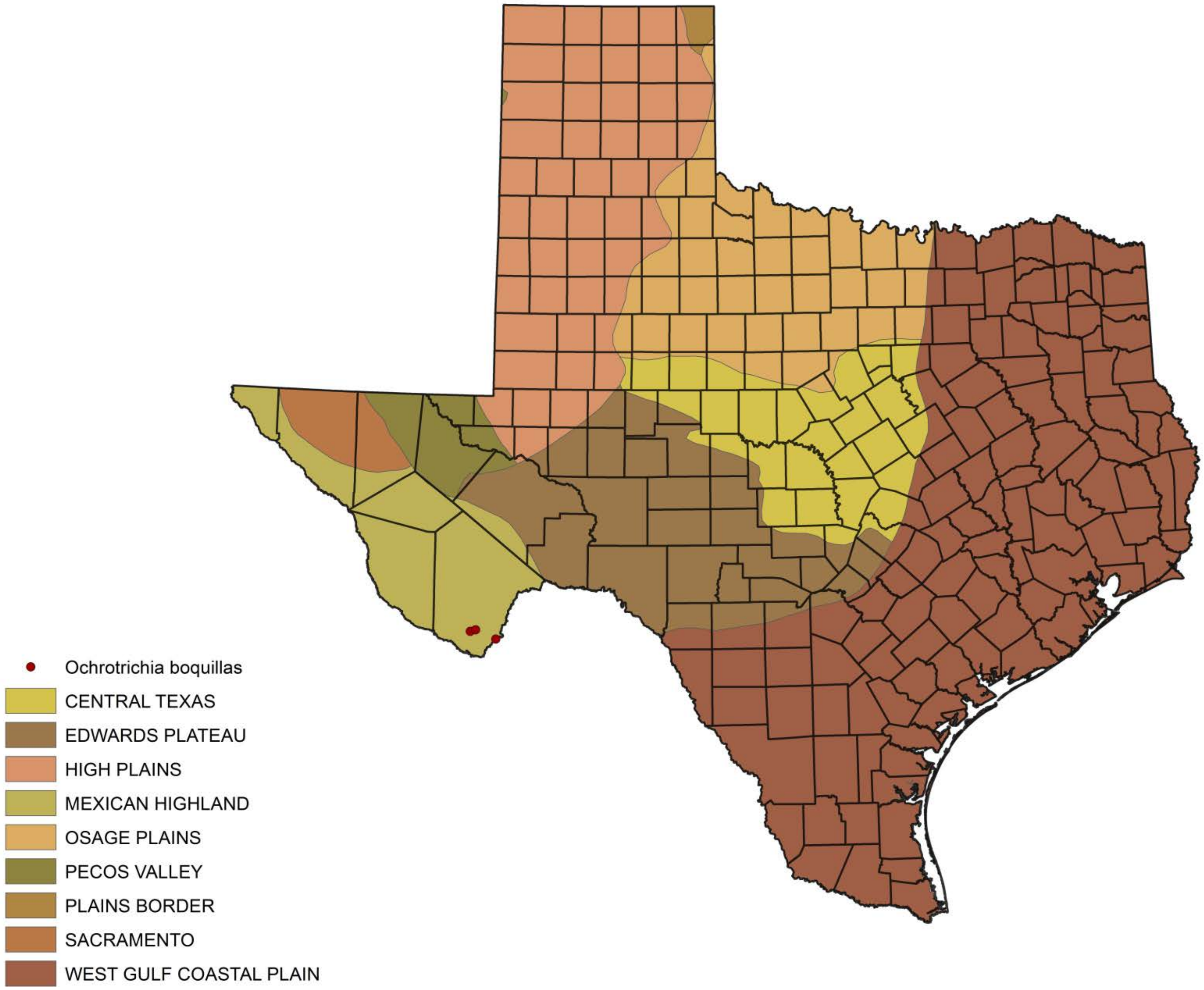
Texas endemic *Neotrichia juani* (Hydroptilidae) by physiographic section (physiographic province: Great Plains).



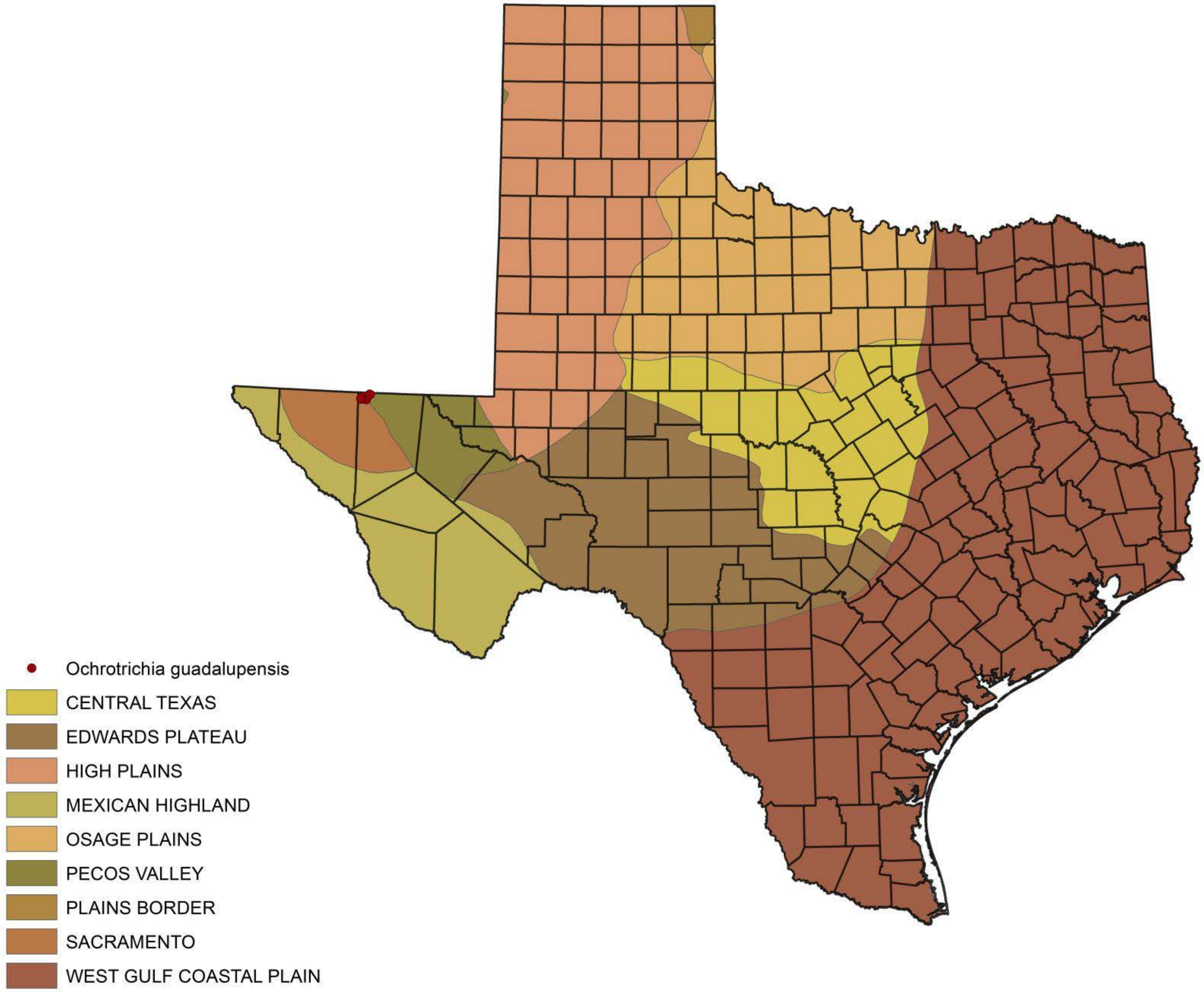
Texas endemic *Neotrichia sonora* (Hydroptilidae) by physiographic section (physiographic provinces: Great Plains and Basin and Range).



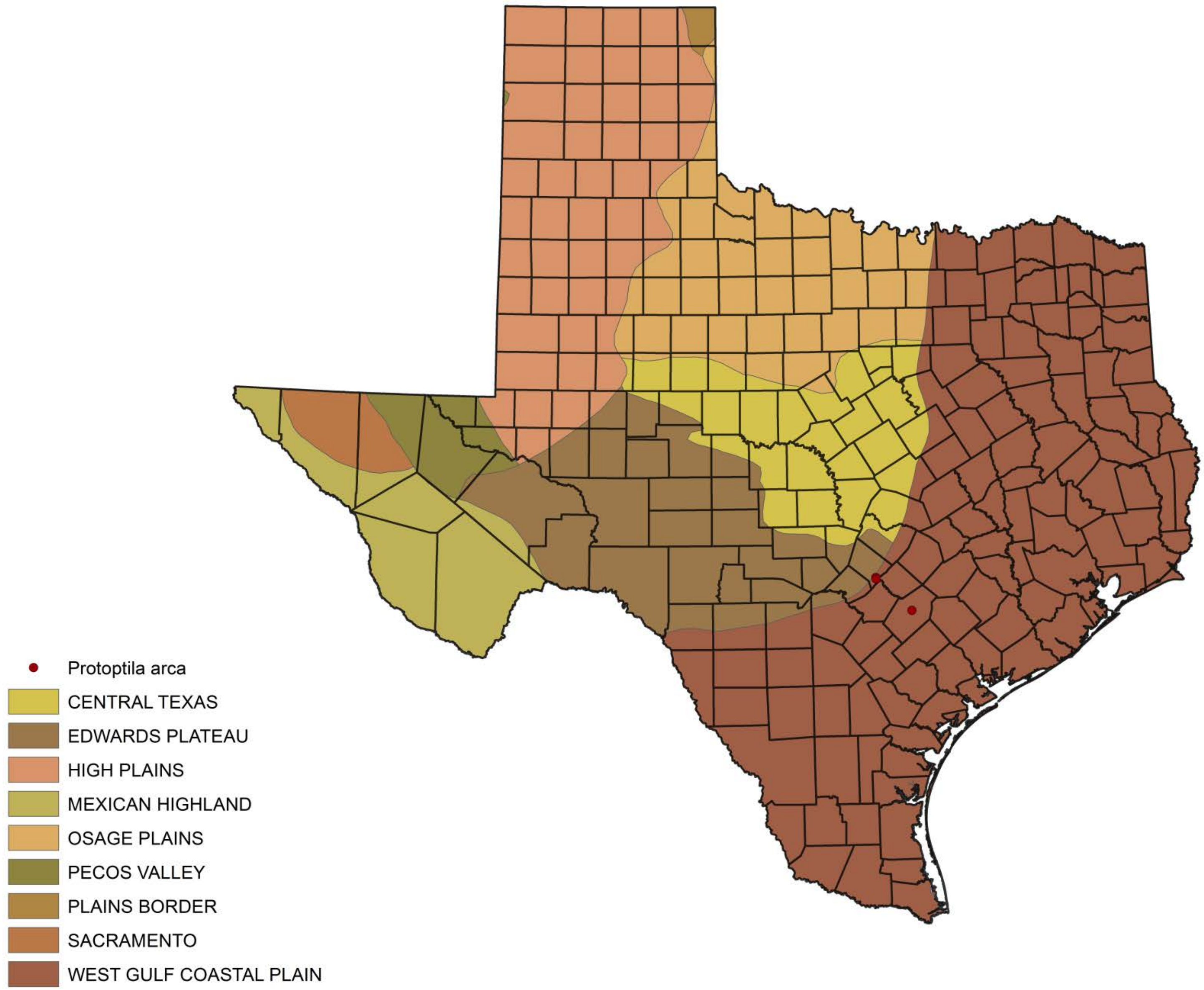
Texas endemic *Ochrotrichia boquillas* (Hydroptilidae) by physiographic section (physiographic province: Basin and Range).



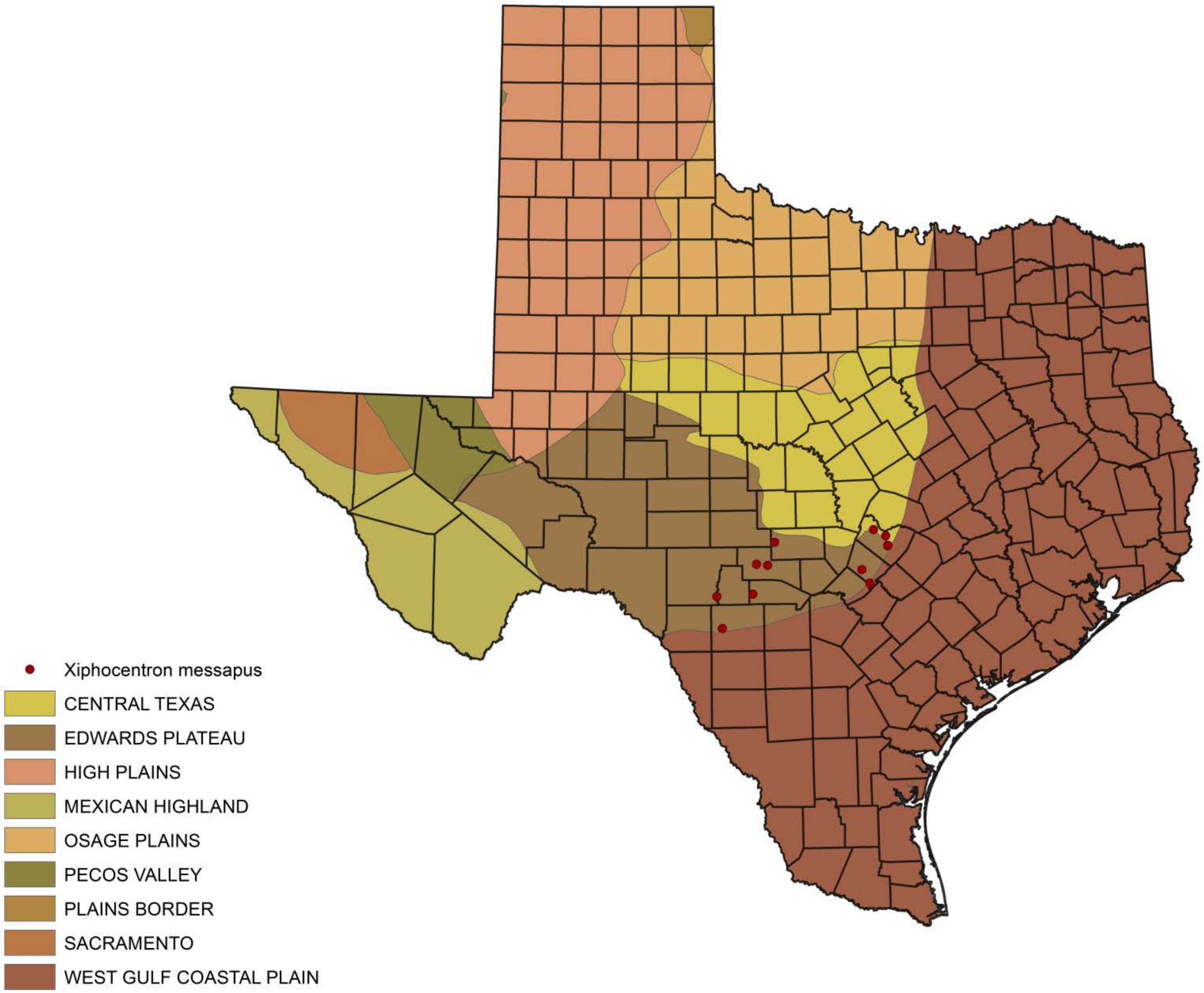
Texas endemic *Ochrotrichia guadalupensis* (Hydroptilidae) by physiographic section (physiographic province: Basin and Range).



Texas endemic *Protoptila arca* (Glossosomatidae) by physiographic section (physiographic province: Coastal Plains).



Texas endemic *Xiphocentron messapus* (Xiphocentronidae) by physiographic section (physiographic province: Great Plains).



The following endemic species do not have maps because they were from published literature accounts and not through NHC records or HAP sampling.

- New Mexico
    - *Lepidostoma deceptivum* (Lepidostomatidae)
    - *Homophylax adriana* (Limnephilidae)
- Texas
    - *Leptonema albovirens*^ (Hydropsychidae)(at greatest extent of range).

APPENDIX E

SIMPER SPECIES SIMILARITY ANALYSES OUTPUT

SIMPER OUTPUT

Note: I removed analyses between southern rocky mountains and other provinces because of low sample size.

Similarity Percentages - species contributions
One-Way Analysis
Data worksheet
Name: Primer10
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 65.00%

Factor Groups

Sample	Province
AR0042	COASTAL PLAIN
AR0095	COASTAL PLAIN
LA0013	COASTAL PLAIN
LA0017	COASTAL PLAIN
LA0024	COASTAL PLAIN
TX0068	COASTAL PLAIN
TX0447	COASTAL PLAIN
TX0548	COASTAL PLAIN
TX0611	COASTAL PLAIN
OK0013	COASTAL PLAIN
TX0166	COASTAL PLAIN
TX0216	COASTAL PLAIN
TX0256	COASTAL PLAIN
TX0374	COASTAL PLAIN
TX0440	COASTAL PLAIN
TX0518	COASTAL PLAIN
TX0612	COASTAL PLAIN
TX0275	COASTAL PLAIN
TX0578	COASTAL PLAIN
TX0609	COASTAL PLAIN
AR0083	COASTAL PLAIN
AR0520	COASTAL PLAIN
LA0039	COASTAL PLAIN
TX0211	COASTAL PLAIN
TX0287	COASTAL PLAIN

TX0339	COASTAL PLAIN
TX0582	COASTAL PLAIN
TX0272	COASTAL PLAIN
TX0316	COASTAL PLAIN
TX0136	COASTAL PLAIN
TX0151	COASTAL PLAIN
TX0271	COASTAL PLAIN
TX0359	COASTAL PLAIN
TX0606	COASTAL PLAIN
LA0020	COASTAL PLAIN
TX0223	COASTAL PLAIN
TX0345	COASTAL PLAIN
TX0586	COASTAL PLAIN
LA0035	COASTAL PLAIN
TX0277	COASTAL PLAIN
TX0289	COASTAL PLAIN
TX0383	COASTAL PLAIN
TX0385	COASTAL PLAIN
TX0425	COASTAL PLAIN
TX0587	COASTAL PLAIN
TX0576	COASTAL PLAIN
AR0043	COASTAL PLAIN
TX0230	COASTAL PLAIN
TX0399	COASTAL PLAIN
LA0076	COASTAL PLAIN
TX0259	COASTAL PLAIN
TX0270	COASTAL PLAIN
TX0285	COASTAL PLAIN
TX0317	COASTAL PLAIN
TX0266	COASTAL PLAIN
TX0284	COASTAL PLAIN
TX0410	COASTAL PLAIN
TX0097	COASTAL PLAIN
TX0334	COASTAL PLAIN
TX0583	COASTAL PLAIN
TX0246	COASTAL PLAIN
TX0574	COASTAL PLAIN
TX0327	COASTAL PLAIN
TX0360	COASTAL PLAIN
TX0351	COASTAL PLAIN
TX0273	COASTAL PLAIN
TX0353	COASTAL PLAIN
TX0575	COASTAL PLAIN
TX0269	COASTAL PLAIN
TX0294	COASTAL PLAIN
TX0346	COASTAL PLAIN

TX0379	COASTAL PLAIN
LA0093	COASTAL PLAIN
TX0282	COASTAL PLAIN
TX0338	COASTAL PLAIN
TX0439	COASTAL PLAIN
TX0443	COASTAL PLAIN
AR0125	OUACHITA
AR0143	OUACHITA
AR0160	OUACHITA
AR0174	OUACHITA
AR0216	OUACHITA
AR0281	OUACHITA
AR0318	OUACHITA
AR0327	OUACHITA
AR0356	OUACHITA
OK0086	OUACHITA
AR0128	OUACHITA
AR0155	OUACHITA
AR0167	OUACHITA
AR0183	OUACHITA
AR0235	OUACHITA
AR0236	OUACHITA
AR0255	OUACHITA
AR0331	OUACHITA
OK0151	OUACHITA
AR0273	OUACHITA
AR0603	OUACHITA
AR0088	OUACHITA
AR0090	OUACHITA
AR0092	OUACHITA
AR0162	OUACHITA
AR0245	OUACHITA
OK0085	OUACHITA
AR0132	OUACHITA
AR0169	OUACHITA
AR0308	OUACHITA
OK0033	OUACHITA
AR0137	OUACHITA
AR0166	OUACHITA
AR0136	OUACHITA
AR0148	OUACHITA
OK0024	OUACHITA
OK0071	OUACHITA
AR0152	OUACHITA
AR0193	OUACHITA
AR0276	OUACHITA

AR0089	OUACHITA
AR0204	OUACHITA
AR0151	OUACHITA
AR0086	OUACHITA
AR0249	OUACHITA
AR0343	OUACHITA
AR0133	OUACHITA
AR0149	OUACHITA
AR0142	OUACHITA
AR0205	OUACHITA
AR0194	OUACHITA
AR0164	OUACHITA
AR0279	OUACHITA
AR0224	OUACHITA
OK0142	OUACHITA
AR0385	OZARK PLATEAUS
AR0596	OZARK PLATEAUS
OK0174	OZARK PLATEAUS
AR0425	OZARK PLATEAUS
AR0450	OZARK PLATEAUS
OK0173	OZARK PLATEAUS
OK0178	OZARK PLATEAUS
AR0403	OZARK PLATEAUS
AR0421	OZARK PLATEAUS
AR0472	OZARK PLATEAUS
AR0537	OZARK PLATEAUS
AR0503	OZARK PLATEAUS
AR0440	OZARK PLATEAUS
AR0400	OZARK PLATEAUS
AR0579	OZARK PLATEAUS
AR0364	OZARK PLATEAUS
AR0457	OZARK PLATEAUS
AR0398	OZARK PLATEAUS
AR0473	OZARK PLATEAUS
AR0595	OZARK PLATEAUS
OK0193	OZARK PLATEAUS
AR0490	OZARK PLATEAUS
AR0508	OZARK PLATEAUS
AR0460	OZARK PLATEAUS
AR0522	OZARK PLATEAUS
NM0184	SOUTHERN ROCKY MOUNTAINS
NM0186	SOUTHERN ROCKY MOUNTAINS
OK0079	CENTRAL LOWLAND
OK0101	CENTRAL LOWLAND
OK0108	CENTRAL LOWLAND

OK0098	CENTRAL LOWLAND
OK0099	CENTRAL LOWLAND
OK0115	CENTRAL LOWLAND
OK0119	CENTRAL LOWLAND
OK0128	CENTRAL LOWLAND
OK0078	CENTRAL LOWLAND
OK0106	CENTRAL LOWLAND
OK0126	CENTRAL LOWLAND
OK0211	CENTRAL LOWLAND
OK0073	CENTRAL LOWLAND
OK0082	CENTRAL LOWLAND
TX0481	CENTRAL LOWLAND
OK0055	CENTRAL LOWLAND
OK0080	CENTRAL LOWLAND
OK0091	CENTRAL LOWLAND
OK0109	CENTRAL LOWLAND
OK0112	CENTRAL LOWLAND
OK0162	CENTRAL LOWLAND
OK0163	CENTRAL LOWLAND
OK0114	CENTRAL LOWLAND
OK0129	CENTRAL LOWLAND
OK0118	CENTRAL LOWLAND
OK0134	CENTRAL LOWLAND
OK0036	CENTRAL LOWLAND
OK0089	CENTRAL LOWLAND
OK0051	CENTRAL LOWLAND
OK0103	CENTRAL LOWLAND
TX0137	GREAT PLAINS
TX0180	GREAT PLAINS
TX0281	GREAT PLAINS
TX0427	GREAT PLAINS
TX0450	GREAT PLAINS
TX0588	GREAT PLAINS
TX0204	GREAT PLAINS
TX0347	GREAT PLAINS
TX0375	GREAT PLAINS
NM0007	GREAT PLAINS
TX0082	GREAT PLAINS
TX0144	GREAT PLAINS
TX0145	GREAT PLAINS
TX0238	GREAT PLAINS
TX0348	GREAT PLAINS
TX0074	GREAT PLAINS
TX0182	GREAT PLAINS
TX0192	GREAT PLAINS
NM0251	GREAT PLAINS

TX0328	GREAT PLAINS
TX0116	GREAT PLAINS
TX0132	GREAT PLAINS
TX0155	GREAT PLAINS
TX0173	GREAT PLAINS
TX0114	GREAT PLAINS
TX0589	GREAT PLAINS
TX0062	GREAT PLAINS
TX0121	GREAT PLAINS
TX0221	GREAT PLAINS
TX0343	GREAT PLAINS
TX0109	GREAT PLAINS
TX0590	GREAT PLAINS
TX0164	GREAT PLAINS
TX0063	GREAT PLAINS
TX0129	GREAT PLAINS
TX0292	GREAT PLAINS
TX0390	GREAT PLAINS
TX0134	GREAT PLAINS
TX0265	GREAT PLAINS
TX0184	GREAT PLAINS
TX0189	GREAT PLAINS
TX0170	GREAT PLAINS
TX0434	BASIN AND RANGE
NM0047	BASIN AND RANGE
TX0302	BASIN AND RANGE
TX0044	BASIN AND RANGE
NM0048	BASIN AND RANGE
NM0054	BASIN AND RANGE
NM0043	BASIN AND RANGE
TX0042	BASIN AND RANGE

Group COASTAL PLAIN
Average similarity: 20.54

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Oecetis inconspicua	0.7	2.52	0.9	12.27	12.27
Ceraclea maculata	0.49	1.22	0.54	5.96	18.22
Cyrnellus fraternus	0.45	1.17	0.49	5.69	23.91
Oecetis persimilis	0.44	0.89	0.47	4.32	28.23
Cheumatopsyche analis	0.42	0.87	0.43	4.25	32.47
Nectopsyche candida	0.42	0.85	0.43	4.14	36.61
Cernotina calcea	0.36	0.73	0.37	3.57	40.18
Hydroptila waubesiana	0.36	0.67	0.36	3.27	43.45
Oecetis nocturna	0.39	0.67	0.4	3.25	46.7
Oecetis ditissa	0.35	0.61	0.35	2.96	49.66

Cheumatopsyche pasella	0.34	0.5	0.34	2.42	52.07
Chimarra obscura	0.31	0.48	0.3	2.36	54.43
Oecetis cinerascens	0.3	0.43	0.29	2.1	56.54
Oxyethira janella	0.29	0.41	0.28	1.98	58.52
Macrostemum carolina	0.29	0.41	0.28	1.98	60.5
Hydropsyche mississippiensis	0.29	0.36	0.28	1.75	62.25
Triaenodes ignitus	0.3	0.35	0.3	1.71	63.96
Hydropsyche rossi	0.26	0.34	0.25	1.67	65.63

Group OUACHITA Average similarity: 25.79					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Polycentropus centralis	0.76	3.66	1.09	14.2	14.2
Chimarra obscura	0.73	3.51	0.98	13.62	27.82
Chimarra feria	0.62	2.52	0.75	9.77	37.59
Helicopsyche limnella	0.45	1.3	0.49	5.03	42.62
Oecetis inconspicua	0.44	1.06	0.46	4.12	46.74
Rhyacophila kiamichi	0.4	0.99	0.41	3.85	50.59
Diplectrona modesta	0.4	0.96	0.42	3.71	54.3
Hydropsyche betteni	0.4	0.91	0.42	3.53	57.83
Cheumatopsyche analis	0.38	0.91	0.39	3.52	61.35
Nyctiophylax affinis	0.36	0.74	0.37	2.85	64.2
Polycentropus harpi	0.33	0.62	0.33	2.41	66.61

Group OZARK PLATEAUS Average similarity: 21.04					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chimarra obscura	0.72	3.07	0.93	14.59	14.59
Cheumatopsyche analis	0.48	1.13	0.48	5.35	19.95
Helicopsyche borealis	0.44	1.04	0.45	4.95	24.9
Potamyia flava	0.44	0.98	0.43	4.65	29.55
Psychomyia flavida	0.4	0.88	0.39	4.19	33.73
Ochrotrichia anisca	0.4	0.85	0.39	4.04	37.78
Agapetus illini	0.4	0.85	0.39	4.04	41.81
Cheumatopsyche minuscula	0.4	0.82	0.39	3.88	45.69
Polycentropus centralis	0.4	0.73	0.39	3.45	49.14
Ceraclea cancellata	0.36	0.73	0.35	3.45	52.59
Oecetis inconspicua	0.4	0.71	0.39	3.35	55.95
Cheumatopsyche oxa	0.4	0.65	0.39	3.11	59.05
Hydroptila hamata	0.36	0.63	0.34	3	62.05
Ceraclea transversa	0.36	0.55	0.34	2.61	64.67
Chimarra feria	0.32	0.52	0.29	2.46	67.12

Group SOUTHERN ROCKY MOUNTAINS Average similarity: 40.82					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%

Brachycentrus americanus	1	4.08	#######	10	10
Cheumatopsyche arizonensis	1	4.08	#######	10	20
Glossosoma ventrale	1	4.08	#######	10	30
Hesperophylax occidentalis	1	4.08	#######	10	40
Hydropsyche occidentalis	1	4.08	#######	10	50
Hydropsyche orris	1	4.08	#######	10	60
Lepidostoma unicolor	1	4.08	#######	10	70
Group CENTRAL LOWLAND					
Average similarity: 45.97					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Oecetis inconspicua	0.97	5.56	2.68	12.09	12.09
Triaenodes tardus	0.8	3.97	1.22	8.63	20.72
Cheumatopsyche campyla	0.77	3.46	1.1	7.52	28.24
Chimarra obscura	0.8	3.32	1.23	7.22	35.47
Cheumatopsyche analis	0.77	3.19	1.09	6.94	42.4
Triaenodes injustus	0.7	2.8	0.91	6.08	48.48
Oecetis avara	0.7	2.74	0.91	5.97	54.45
Potamyia flava	0.7	2.5	0.91	5.45	59.9
Hydropsyche bidens	0.63	2.34	0.76	5.1	65
Oecetis cinerascens	0.63	2.17	0.76	4.71	69.71
Group GREAT PLAINS					
Average similarity: 23.72					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chimarra obscura	0.52	1.62	0.58	6.81	6.81
Cheumatopsyche comis	0.52	1.48	0.58	6.23	13.04
Ochrotrichia tarsalis	0.5	1.41	0.54	5.96	19
Oecetis avara	0.5	1.35	0.54	5.67	24.67
Polycentropus picana	0.48	1.24	0.51	5.25	29.92
Cernotina calcea	0.45	1.18	0.48	4.99	34.91
Helicopsyche borealis	0.43	1.04	0.44	4.4	39.31
Oecetis inconspicua	0.45	1.04	0.48	4.38	43.69
Smicridea fasciatella	0.43	0.99	0.45	4.15	47.84
Oxyethira azteca	0.38	0.79	0.39	3.33	51.17
Polyplectropus santiago	0.38	0.76	0.38	3.2	54.37
Hydroptila angusta	0.33	0.61	0.33	2.59	56.97
Hydroptila protera	0.33	0.58	0.33	2.43	59.39
Cheumatopsyche analis	0.31	0.56	0.31	2.35	61.74
Hydroptila icona	0.33	0.52	0.33	2.21	63.95
Ochrotrichia capitana	0.31	0.5	0.3	2.09	66.04
Group BASIN AND RANGE					
Average similarity: 28.58					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Hydroptila arctia	0.88	5.84	1.63	20.43	20.43
Ochrotrichia dactylophora	0.88	5.57	1.65	19.48	39.91

Chimarra ridleyi	0.63	2.44	0.72	8.55	48.47
Helicopsyche mexicana	0.5	1.84	0.51	6.44	54.9
Ochrotrichia rothi	0.5	1.67	0.5	5.83	60.74
Polycentropus halidus	0.5	1.66	0.51	5.8	66.53

Groups COASTAL PLAIN & OUACHITA
Average dissimilarity = 90.43

PROVINCE	COASTAL PLAIN	OUACHITA				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polycentropus centralis	0.01	0.76	2.31	1.54	2.55	2.55
Chimarra feria	0.04	0.62	1.91	1.15	2.11	4.66
Chimarra obscura	0.31	0.73	1.87	1.1	2.07	6.73
Oecetis inconspicua	0.7	0.44	1.67	0.99	1.84	8.58
Cheumatopsyche analis	0.42	0.38	1.49	0.89	1.64	10.22
Ceraclea maculata	0.49	0.13	1.47	0.93	1.62	11.84
Cyrnellus fraternus	0.45	0.11	1.45	0.88	1.61	13.45
Helicopsyche limnella	0.01	0.45	1.4	0.86	1.55	15
Oecetis nocturna	0.39	0.22	1.27	0.82	1.41	16.41
Cernotina calcea	0.36	0.16	1.27	0.78	1.4	17.81
Nectopsyche candida	0.42	0.07	1.26	0.8	1.39	19.2
Oecetis persimilis	0.44	0.05	1.25	0.85	1.39	20.58
Oecetis ditissa	0.35	0.22	1.24	0.78	1.38	21.96
Rhyacophila kiamichi	0.01	0.4	1.24	0.77	1.37	23.33
Diplectrona modesta	0.04	0.4	1.23	0.79	1.36	24.68
Hydropsyche betteni	0.01	0.4	1.19	0.78	1.31	26
Nyctiophylax affinis	0.09	0.36	1.14	0.75	1.26	27.26
Hydroptila waubesiana	0.36	0.04	1.11	0.72	1.22	28.48
Oecetis avara	0.19	0.2	1	0.65	1.11	29.59
Psychomyia flavida	0.04	0.31	0.99	0.66	1.1	30.69
Cheumatopsyche oxa	0.01	0.33	0.99	0.67	1.09	31.78
Polycentropus harpi	0	0.33	0.97	0.67	1.08	32.86
Macrostemum carolina	0.29	0.09	0.97	0.65	1.07	33.93
Cheumatopsyche pasella	0.34	0.04	0.97	0.69	1.07	35
Agapetus medicus	0.03	0.31	0.96	0.65	1.06	36.07
Triaenodes ignitus	0.3	0.13	0.95	0.69	1.05	37.12
Wormaldia moesta	0	0.33	0.93	0.66	1.03	38.14
Oecetis cinerascens	0.3	0.05	0.93	0.64	1.02	39.17
Orthotrichia aegerfasciella	0.23	0.11	0.91	0.6	1	40.17
Ceraclea tarsipunctata	0.13	0.22	0.89	0.61	0.98	41.15
Hydropsyche rossi	0.26	0.05	0.87	0.59	0.97	42.12
Cheumatopsyche robisoni	0	0.29	0.86	0.61	0.95	43.06
Oxyethira janella	0.29	0	0.84	0.6	0.93	44
Potamyia flava	0.22	0.11	0.84	0.59	0.92	44.92
Phylocentropus placidus	0.29	0.04	0.8	0.62	0.89	45.81

Hydropsyche mississippiensis	0.29	0	0.78	0.61	0.87	46.67
Agrypnia vestita	0.09	0.22	0.78	0.57	0.86	47.54
Chimarra parasocia	0.27	0	0.76	0.58	0.84	48.38
Hydroptila grandiosa	0.08	0.2	0.75	0.54	0.83	49.21
Lype diversa	0.17	0.15	0.75	0.57	0.83	50.04
Nectopsyche pavida	0.18	0.13	0.74	0.56	0.82	50.86
Rhyacophila glaberrima	0	0.25	0.74	0.56	0.82	51.68
Nectopsyche exquisita	0.03	0.22	0.74	0.52	0.81	52.49
Hydroptila quinola	0.25	0.04	0.73	0.57	0.8	53.3
Oecetis osteni	0.27	0.02	0.73	0.59	0.8	54.1
Oxyethira novasota	0.25	0.04	0.72	0.56	0.79	54.89
Mayatrichia ayama	0.23	0.02	0.67	0.54	0.74	55.64
Hydroptila hamata	0.03	0.2	0.67	0.5	0.74	56.38
Cheumatopsyche campyla	0.12	0.13	0.66	0.49	0.73	57.12
Cheumatopsyche burksi	0.21	0.04	0.65	0.51	0.72	57.84
Cheumatopsyche minuscula	0.01	0.22	0.64	0.51	0.71	58.55
Hydroptila scolops	0.21	0	0.63	0.49	0.7	59.25
Oxyethira zeronia	0.19	0.04	0.61	0.49	0.67	59.92
Ochrotrichia anisca	0	0.2	0.61	0.47	0.67	60.59
Leptocerus americanus	0.19	0.05	0.59	0.52	0.65	61.24
Nyctiophylax serratus	0.22	0.02	0.59	0.52	0.65	61.89
Agapetus illini	0	0.2	0.58	0.47	0.64	62.53
Ironoquia punctatissima	0.01	0.2	0.57	0.48	0.63	63.16
Hydroptila lloganae	0.21	0	0.57	0.48	0.63	63.79
Ceraclea transversa	0.06	0.16	0.56	0.48	0.62	64.41
Cernotina spicata	0.19	0.02	0.56	0.49	0.62	65.03

Groups COASTAL PLAIN & OZARK PLATEAUS
Average dissimilarity = 89.89

PROVINCE	COASTAL PLAIN	OZARK PLATEAUS				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chimarra obscura	0.31	0.72	1.78	1.08	1.97	1.97
Oecetis inconspicua	0.7	0.4	1.64	1	1.83	3.8
Cheumatopsyche analis	0.42	0.48	1.46	0.91	1.63	5.43
Ceraclea maculata	0.49	0.24	1.44	0.91	1.6	7.03
Cyrnellus fraternus	0.45	0.12	1.38	0.87	1.54	8.57
Potamyia flava	0.22	0.44	1.35	0.85	1.5	10.07
Helicopsyche borealis	0.05	0.44	1.3	0.84	1.45	11.52
Oecetis persimilis	0.44	0.16	1.26	0.85	1.4	12.92
Cernotina calcea	0.36	0.24	1.25	0.8	1.39	14.31
Psychomyia flavida	0.04	0.4	1.21	0.76	1.35	15.65
Nectopsyche candida	0.42	0.12	1.2	0.81	1.34	16.99
Ochrotrichia anisca	0	0.4	1.16	0.75	1.29	18.29
Agapetus illini	0	0.4	1.16	0.75	1.29	19.58
Cheumatopsyche minuscula	0.01	0.4	1.15	0.75	1.28	20.85

Oecetis nocturna	0.39	0.12	1.14	0.78	1.27	22.12
Oecetis ditissa	0.35	0.16	1.13	0.75	1.26	23.38
Ceraclea cancellata	0.03	0.36	1.1	0.71	1.22	24.6
Polycentropus centralis	0.01	0.4	1.08	0.76	1.21	25.81
Hydroptila waubesiana	0.36	0.04	1.06	0.71	1.18	26.98
Oecetis avara	0.19	0.24	1.05	0.67	1.17	28.15
Hydroptila hamata	0.03	0.36	1.03	0.7	1.15	29.31
Cheumatopsyche oxa	0.01	0.4	1.03	0.75	1.14	30.45
Nectopsyche pavida	0.18	0.28	1.01	0.69	1.13	31.58
Cheumatopsyche campyla	0.12	0.32	0.99	0.69	1.1	32.68
Ceraclea transversa	0.06	0.36	0.98	0.71	1.09	33.77
Chimarra feria	0.04	0.32	0.96	0.64	1.07	34.84
Chimarra aterrima	0.16	0.28	0.96	0.68	1.06	35.91
Triaenodes ignitus	0.3	0.12	0.92	0.68	1.03	36.93
Hydropsyche simulans	0.05	0.28	0.91	0.61	1.02	37.95
Cheumatopsyche pasella	0.34	0.04	0.91	0.69	1.01	38.96
Ceraclea tarsipunctata	0.13	0.24	0.89	0.62	0.99	39.95
Oecetis cinerascens	0.3	0.04	0.86	0.63	0.96	40.91
Macrostemum carolina	0.29	0.04	0.84	0.61	0.94	41.85
Hydroptila perdita	0.01	0.32	0.81	0.63	0.9	42.75
Oxyethira janella	0.29	0	0.81	0.59	0.9	43.65
Orthotrichia aegerfasciella	0.23	0.08	0.77	0.56	0.85	44.5
Cheumatopsyche burksi	0.21	0.12	0.76	0.57	0.84	45.34
Hydropsyche mississippiensis	0.29	0	0.75	0.6	0.84	46.18
Hydropsyche rossi	0.26	0	0.74	0.55	0.83	47.01
Hydroptila virgata	0	0.28	0.73	0.58	0.81	47.82
Chimarra parasocia	0.27	0	0.73	0.58	0.81	48.63
Phylocentropus placidus	0.29	0	0.73	0.59	0.81	49.43
Oecetis osteni	0.27	0.04	0.71	0.6	0.79	50.23
Ceraclea ancylus	0.01	0.2	0.7	0.49	0.77	51
Paduniella nearctica	0	0.24	0.68	0.53	0.76	51.76
Neotrichia vibrans	0.19	0.08	0.66	0.53	0.73	52.49
Rhyacophila kiamichi	0.01	0.24	0.65	0.53	0.73	53.22
Hydropsyche scalaris	0.03	0.24	0.65	0.53	0.72	53.94
Neureclipsis crepuscularis	0.17	0.08	0.64	0.5	0.72	54.65
Plectrocnemia cinerea	0.06	0.24	0.64	0.57	0.71	55.36
Ceraclea nepha	0.12	0.12	0.63	0.48	0.7	56.07
Nyctiophylax affinis	0.09	0.2	0.63	0.54	0.7	56.77
Hydroptila quinola	0.25	0	0.63	0.54	0.7	57.47
Oxyethira novasota	0.25	0	0.62	0.53	0.69	58.16
Mayatrichia ayama	0.23	0	0.62	0.52	0.69	58.85
Oxyethira pallida	0.13	0.12	0.62	0.49	0.69	59.54
Leptocerus americanus	0.19	0.08	0.61	0.53	0.68	60.21
Hydroptila scolops	0.21	0	0.61	0.48	0.67	60.89

Hydropsyche incommoda	0.04	0.2	0.6	0.49	0.67	61.56
Nectopsyche exquisita	0.03	0.2	0.59	0.48	0.66	62.22
Hydropsyche orris	0.14	0.08	0.57	0.47	0.64	62.85
Hydroptila lloganae	0.21	0	0.54	0.48	0.6	63.46
Lype diversa	0.17	0.04	0.53	0.47	0.59	64.05
Nyctiophylax serratus	0.22	0	0.53	0.51	0.59	64.64
Oxyethira zeronia	0.19	0	0.52	0.46	0.58	65.22

Groups OUACHITA & OZARK PLATEAUS
Average dissimilarity = 81.01

PROVINCE	OUACHITA	OZARK PLATEAUS				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polycentropus centralis	0.76	0.4	1.85	1.03	2.28	2.28
Chimarra feria	0.62	0.32	1.77	1.01	2.18	4.46
Cheumatopsyche analis	0.38	0.48	1.57	0.91	1.94	6.4
Oecetis inconspicua	0.44	0.4	1.52	0.9	1.88	8.28
Psychomyia flavida	0.31	0.4	1.48	0.86	1.83	10.11
Helicopsyche limnella	0.45	0.08	1.46	0.86	1.8	11.91
Helicopsyche borealis	0.09	0.44	1.41	0.85	1.74	13.65
Rhyacophila kiamichi	0.4	0.24	1.41	0.83	1.74	15.39
Cheumatopsyche oxa	0.33	0.4	1.41	0.87	1.74	17.13
Ochrotrichia anisca	0.2	0.4	1.39	0.82	1.72	18.85
Potamyia flava	0.11	0.44	1.39	0.83	1.72	20.56
Agapetus illini	0.2	0.4	1.38	0.82	1.71	22.27
Cheumatopsyche minuscula	0.22	0.4	1.38	0.83	1.7	23.97
Diplectrona modesta	0.4	0.16	1.34	0.82	1.65	25.63
Chimarra obscura	0.73	0.72	1.32	0.77	1.63	27.26
Hydropsyche betteni	0.4	0.16	1.32	0.82	1.63	28.88
Hydroptila hamata	0.2	0.36	1.3	0.78	1.6	30.48
Ceraclea cancellata	0.13	0.36	1.26	0.76	1.55	32.03
Nyctiophylax affinis	0.36	0.2	1.24	0.79	1.54	33.57
Ceraclea transversa	0.16	0.36	1.19	0.76	1.47	35.04
Oecetis avara	0.2	0.24	1.15	0.68	1.41	36.45
Ceraclea tarsipunctata	0.22	0.24	1.12	0.69	1.38	37.83
Cheumatopsyche campyla	0.13	0.32	1.07	0.7	1.32	39.15
Wormaldia moesta	0.33	0.12	1.06	0.72	1.31	40.45
Polycentropus harpi	0.33	0.04	1.05	0.68	1.3	41.75
Nectopsyche exquisita	0.22	0.2	1.02	0.65	1.26	43.01
Nectopsyche pavida	0.13	0.28	1.02	0.65	1.26	44.27
Agapetus medicus	0.31	0.04	1.01	0.66	1.25	45.53
Ceraclea ancylus	0.16	0.2	1	0.62	1.24	46.76
Hydroptila perdita	0.07	0.32	0.96	0.66	1.18	47.94
Cernotina calcea	0.16	0.24	0.95	0.64	1.17	49.11
Ceraclea maculata	0.13	0.24	0.94	0.62	1.16	50.28
Hydropsyche simulans	0.02	0.28	0.92	0.59	1.14	51.42

Oecetis ditissa	0.22	0.16	0.92	0.62	1.13	52.55
Oecetis nocturna	0.22	0.12	0.91	0.6	1.12	53.67
Chimarra aterrima	0.05	0.28	0.9	0.62	1.11	54.78
Cheumatopsyche robisoni	0.29	0	0.88	0.61	1.09	55.87
Hydroptila virgata	0.07	0.28	0.88	0.62	1.08	56.95
Hydroptila grandiosa	0.2	0.12	0.85	0.57	1.05	58
Paduniella nearctica	0.05	0.24	0.83	0.57	1.03	59.03
Hydropsyche scalaris	0.11	0.24	0.83	0.6	1.03	60.06
Cheumatopsyche aphanta	0.16	0.2	0.83	0.6	1.02	61.08
Rhyacophila glaberrima	0.25	0.04	0.82	0.59	1.01	62.09
Plectrocnemia cinerea	0.09	0.24	0.79	0.58	0.97	63.07
Wormaldia strota	0.18	0.12	0.72	0.55	0.89	63.96
Triaenodes ignitus	0.13	0.12	0.68	0.5	0.83	64.8
Agrypnia vestita	0.22	0	0.63	0.5	0.78	65.58

Groups COASTAL PLAIN & CENTRAL LOWLAND
Average dissimilarity = 80.73

PROVINCE	COASTAL PLAIN	CENTRAL LOWLAND				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/S	Contrib%	Cum.%
Triaenodes tardus	0.08	0.8	2.32	1.54	2.87	2.87
Cheumatopsyche campyla	0.12	0.77	2.08	1.38	2.58	5.45
Triaenodes injustus	0.05	0.7	1.98	1.3	2.45	7.9
Hydropsyche bidens	0.09	0.63	1.81	1.14	2.24	10.14
Oecetis avara	0.19	0.7	1.81	1.16	2.24	12.38
Chimarra obscura	0.31	0.8	1.77	1.16	2.2	14.58
Potamyia flava	0.22	0.7	1.74	1.15	2.15	16.73
Cheumatopsyche analis	0.42	0.77	1.62	1.02	2.01	18.74
Oecetis cinerascens	0.3	0.63	1.62	1.03	2	20.74
Cheumatopsyche lasia	0.13	0.57	1.53	1.03	1.9	22.64
Hydropsyche simulans	0.05	0.53	1.51	0.97	1.87	24.51
Cyrnellus fraternus	0.45	0.43	1.44	0.92	1.78	26.29
Ceraclea maculata	0.49	0.43	1.44	0.93	1.78	28.07
Cernotina calcea	0.36	0.37	1.33	0.87	1.65	29.72
Hydropsyche orris	0.14	0.47	1.31	0.9	1.62	31.34
Helicopsyche borealis	0.05	0.47	1.31	0.86	1.62	32.97
Oecetis ditissa	0.35	0.33	1.3	0.84	1.61	34.58
Orthotrichia aegerfasciella	0.23	0.37	1.23	0.81	1.52	36.1
Oecetis persimilis	0.44	0.17	1.22	0.87	1.52	37.62
Nectopsyche candida	0.42	0.1	1.18	0.82	1.46	39.08
Oecetis nocturna	0.39	0.2	1.16	0.82	1.44	40.52
Nyctiophylax affinis	0.09	0.37	1.07	0.76	1.33	41.85
Hydroptila waubesiana	0.36	0.07	1.06	0.73	1.31	43.16
Oecetis inconspicua	0.7	0.97	1.03	0.65	1.28	44.44
Smicridea fasciatella	0.13	0.33	0.99	0.74	1.23	45.66
Leptocerus americanus	0.19	0.27	0.97	0.71	1.21	46.87

Ochrotrichia tarsalis	0.06	0.33	0.89	0.71	1.11	47.98
Hydroptila ajax	0.13	0.27	0.89	0.66	1.1	49.08
Cheumatopsyche pasella	0.34	0.03	0.88	0.7	1.1	50.17
Cernotina spicata	0.19	0.23	0.88	0.68	1.1	51.27
Oxyethira janella	0.29	0.07	0.86	0.64	1.07	52.33
Oxyethira pallida	0.13	0.27	0.85	0.66	1.05	53.38
Hydropsyche rossi	0.26	0.07	0.8	0.6	0.99	54.38
Hydropsyche scalaris	0.03	0.3	0.79	0.64	0.98	55.36
Oxyethira zeronia	0.19	0.17	0.79	0.61	0.97	56.33
Macrostemum carolina	0.29	0	0.78	0.59	0.97	57.3
Hydroptila angusta	0.1	0.23	0.77	0.61	0.96	58.26
Chimarra feria	0.04	0.27	0.77	0.6	0.95	59.21
Helicopsyche piroa	0.13	0.2	0.74	0.59	0.91	60.12
Hydropsyche mississippiensis	0.29	0	0.73	0.61	0.91	61.03
Triaenodes ignitus	0.3	0	0.72	0.62	0.89	61.92
Phylocentropus placidus	0.29	0	0.71	0.6	0.88	62.8
Chimarra parasocia	0.27	0	0.71	0.58	0.88	63.67
Orthotrichia cristata	0.14	0.17	0.71	0.56	0.88	64.55
Nectopsyche pavida	0.18	0.13	0.67	0.58	0.83	65.38
Groups OUACHITA & CENTRAL LOWLAND						
Average dissimilarity = 84.69						
PROVINCE	OUACHITA	CENTRAL LOWLAND				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/S	Contrib%	Cum.%
Triaenodes tardus	0.02	0.8	2.59	1.71	3.06	3.06
Cheumatopsyche campyla	0.13	0.77	2.23	1.39	2.63	5.69
Polycentropus centralis	0.76	0.1	2.19	1.41	2.58	8.27
Triaenodes injustus	0.07	0.7	2.11	1.3	2.49	10.77
Hydropsyche bidens	0	0.63	2.02	1.21	2.38	13.15
Potamyia flava	0.11	0.7	1.96	1.27	2.32	15.47
Oecetis avara	0.2	0.7	1.93	1.17	2.28	17.75
Oecetis cinerascens	0.05	0.63	1.9	1.17	2.25	20
Oecetis inconspicua	0.44	0.97	1.87	1.06	2.21	22.21
Cheumatopsyche analis	0.38	0.77	1.77	1.06	2.09	24.3
Chimarra feria	0.62	0.27	1.75	1.05	2.07	26.37
Cheumatopsyche lasia	0	0.57	1.67	1.07	1.97	28.33
Hydropsyche simulans	0.02	0.53	1.62	0.99	1.91	30.24
Helicopsyche borealis	0.09	0.47	1.41	0.88	1.67	31.91
Nyctiophylax affinis	0.36	0.37	1.4	0.88	1.65	33.56
Helicopsyche limnella	0.45	0.03	1.4	0.87	1.65	35.22
Cyrnellus fraternus	0.11	0.43	1.36	0.85	1.61	36.83
Hydropsyche orris	0.05	0.47	1.36	0.89	1.61	38.43
Ceraclea maculata	0.13	0.43	1.34	0.86	1.58	40.02
Oecetis ditissa	0.22	0.33	1.27	0.78	1.49	41.51
Cernotina calcea	0.16	0.37	1.23	0.79	1.45	42.96

Rhyacophila kiamichi	0.4	0	1.22	0.77	1.44	44.41
Chimarra obscura	0.73	0.8	1.22	0.72	1.44	45.84
Diplectrona modesta	0.4	0	1.2	0.78	1.42	47.26
Orthotrichia aegerfasciella	0.11	0.37	1.2	0.77	1.41	48.67
Hydropsyche betteni	0.4	0	1.17	0.78	1.38	50.05
Oecetis nocturna	0.22	0.2	0.99	0.66	1.17	51.22
Polycentropus harpi	0.33	0	0.97	0.67	1.15	52.37
Cheumatopsyche oxa	0.33	0	0.97	0.67	1.14	53.51
Hydropsyche scalaris	0.11	0.3	0.95	0.69	1.12	54.63
Psychomyia flavida	0.31	0	0.94	0.64	1.11	55.74
Wormaldia moesta	0.33	0	0.93	0.66	1.09	56.83
Agapetus medicus	0.31	0	0.92	0.64	1.08	57.91
Hydroptila hamata	0.2	0.17	0.9	0.63	1.06	58.97
Smicridea fasciatella	0	0.33	0.88	0.68	1.04	60.01
Ochrotrichia tarsalis	0.02	0.33	0.88	0.69	1.04	61.05
Cheumatopsyche robisoni	0.29	0	0.85	0.62	1.01	62.06
Leptocerus americanus	0.05	0.27	0.84	0.61	0.99	63.05
Oxyethira pallida	0.05	0.27	0.76	0.62	0.9	63.95
Hydroptila ajax	0	0.27	0.76	0.57	0.9	64.85
Rhyacophila glaberrima	0.25	0	0.74	0.56	0.87	65.72
Groups OZARK PLATEAUS & CENTRAL LOWLAND						
Average dissimilarity = 81.33						
PROVINCES	OZARK PLATEAUS	CENTRAL LOWLAND				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/S	Contrib%	Cum.%
Triaenodes tardus	0.08	0.8	2.38	1.52	2.93	2.93
Triaenodes injustus	0.08	0.7	2.02	1.26	2.49	5.41
Oecetis inconspicua	0.4	0.97	1.94	1.13	2.38	7.79
Hydropsyche bidens	0.04	0.63	1.9	1.16	2.34	10.13
Cheumatopsyche campyla	0.32	0.77	1.88	1.11	2.31	12.44
Oecetis cinerascens	0.04	0.63	1.83	1.16	2.25	14.69
Oecetis avara	0.24	0.7	1.79	1.12	2.2	16.89
Cheumatopsyche lasia	0	0.57	1.6	1.05	1.96	18.86
Cheumatopsyche analis	0.48	0.77	1.59	0.96	1.96	20.81
Potamyia flava	0.44	0.7	1.59	0.98	1.95	22.76
Hydropsyche simulans	0.28	0.53	1.52	0.94	1.87	24.64
Helicopsyche borealis	0.44	0.47	1.47	0.91	1.81	26.45
Ceraclea maculata	0.24	0.43	1.36	0.87	1.67	28.12
Hydropsyche orris	0.08	0.47	1.32	0.88	1.62	29.74
Cyrnellus fraternus	0.12	0.43	1.3	0.84	1.6	31.33
Cernotina calcea	0.24	0.37	1.21	0.82	1.49	32.82
Chimarra feria	0.32	0.27	1.2	0.78	1.48	34.3
Chimarra obscura	0.72	0.8	1.18	0.72	1.45	35.75
Psychomyia flavida	0.4	0	1.18	0.75	1.45	37.2
Nyctiophylax affinis	0.2	0.37	1.16	0.8	1.43	38.63

Ochrotrichia anisca	0.4	0	1.16	0.76	1.42	40.05
Agapetus illini	0.4	0	1.16	0.75	1.42	41.47
Oecetis ditissa	0.16	0.33	1.15	0.74	1.42	42.89
Hydroptila hamata	0.36	0.17	1.15	0.77	1.41	44.3
Ceraclea cancellata	0.36	0.1	1.14	0.75	1.41	45.71
Polycentropus centralis	0.4	0.1	1.14	0.79	1.4	47.11
Cheumatopsyche minuscula	0.4	0	1.13	0.75	1.39	48.5
Orthotrichia aegerfasciella	0.08	0.37	1.09	0.75	1.34	49.84
Hydropsyche scalaris	0.24	0.3	1.04	0.76	1.28	51.12
Cheumatopsyche oxa	0.4	0	1.01	0.75	1.24	52.37
Ceraclea transversa	0.36	0	0.94	0.69	1.15	53.52
Nectopsyche pavida	0.28	0.13	0.93	0.66	1.14	54.66
Ochrotrichia tarsalis	0.08	0.33	0.87	0.71	1.07	55.73
Oxyethira pallida	0.12	0.27	0.85	0.65	1.04	56.78
Smicridea fasciatella	0	0.33	0.85	0.67	1.04	57.82
Leptocerus americanus	0.08	0.27	0.84	0.62	1.03	58.85
Oecetis nocturna	0.12	0.2	0.8	0.58	0.98	59.83
Hydroptila perdita	0.32	0	0.79	0.63	0.97	60.79
Chimarra aterrima	0.28	0	0.77	0.58	0.94	61.74
Hydroptila virgata	0.28	0.03	0.76	0.6	0.94	62.68
Hydroptila ajax	0	0.27	0.73	0.56	0.89	63.57
Oecetis persimilis	0.16	0.17	0.7	0.57	0.86	64.43
Ceraclea tarsipunctata	0.24	0	0.69	0.53	0.84	65.27

Groups COASTAL PLAIN & GREAT PLAINS
Average dissimilarity = 90.09

PROVINCE	COASTAL PLAIN	GREAT PLAINS				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oecetis inconspicua	0.7	0.45	1.61	0.98	1.79	1.79
Chimarra obscura	0.31	0.52	1.55	0.95	1.72	3.51
Cheumatopsyche comis	0.01	0.52	1.49	0.97	1.66	5.16
Cernotina calcea	0.36	0.45	1.48	0.91	1.64	6.81
Ochrotrichia tarsalis	0.06	0.5	1.47	0.93	1.63	8.44
Oecetis avara	0.19	0.5	1.47	0.93	1.63	10.07
Ceraclea maculata	0.49	0.19	1.45	0.93	1.61	11.68
Cyrnellus fraternus	0.45	0.1	1.41	0.88	1.56	13.24
Cheumatopsyche analis	0.42	0.31	1.4	0.88	1.55	14.79
Polycentropus picana	0.01	0.48	1.38	0.89	1.53	16.32
Smicridea fasciatella	0.13	0.43	1.3	0.84	1.45	17.77
Helicopsyche borealis	0.05	0.43	1.29	0.82	1.43	19.2
Oecetis persimilis	0.44	0.02	1.21	0.84	1.34	20.54
Nectopsyche candida	0.42	0.02	1.19	0.79	1.32	21.86
Hydroptila waubesiana	0.36	0.1	1.14	0.75	1.26	23.12
Oxyethira azteca	0.03	0.38	1.13	0.75	1.25	24.37
Hydroptila angusta	0.1	0.33	1.09	0.72	1.21	25.58

Polyplectropus santiago	0	0.38	1.08	0.73	1.2	26.78
Oecetis ditissa	0.35	0.05	1.04	0.71	1.16	27.94
Oecetis nocturna	0.39	0	1.03	0.75	1.15	29.09
Oxyethira pallida	0.13	0.29	1.02	0.68	1.13	30.23
Oecetis cinerascens	0.3	0.14	1.02	0.7	1.13	31.36
Cheumatopsyche campyla	0.12	0.29	1	0.67	1.11	32.47
Hydroptila protera	0.01	0.33	0.97	0.67	1.07	33.54
Oxyethira janella	0.29	0.1	0.96	0.66	1.06	34.6
Orthotrichia cristata	0.14	0.24	0.93	0.64	1.04	35.64
Hydroptila icona	0.03	0.33	0.93	0.68	1.04	36.67
Nyctiophylax affinis	0.09	0.29	0.93	0.65	1.03	37.7
Cheumatopsyche pasella	0.34	0.02	0.92	0.69	1.02	38.73
Ochrotrichia capitana	0.01	0.31	0.9	0.63	1	39.73
Chimarra angustipennis	0.03	0.31	0.9	0.64	1	40.73
Triaenodes ignitus	0.3	0.1	0.88	0.68	0.98	41.71
Orthotrichia aegerfasciella	0.23	0.1	0.87	0.59	0.97	42.67
Nectopsyche gracilis	0.01	0.31	0.85	0.64	0.94	43.61
Macrostemum carolina	0.29	0	0.82	0.59	0.91	44.52
Mayatrichia ayama	0.23	0.12	0.81	0.62	0.9	45.42
Marilia flexuosa	0	0.26	0.8	0.57	0.89	46.31
Oxyethira ulmeri	0.03	0.29	0.79	0.62	0.88	47.18
Hydroptila ajax	0.13	0.17	0.76	0.55	0.85	48.03
Hydropsyche mississippiensis	0.29	0	0.76	0.61	0.85	48.88
Hydropsyche rossi	0.26	0	0.76	0.56	0.84	49.72
Chimarra parasocia	0.27	0	0.74	0.58	0.82	50.54
Phylocentropus placidus	0.29	0	0.74	0.6	0.82	51.36
Hydropsyche simulans	0.05	0.24	0.73	0.57	0.81	52.18
Neureclipsis crepuscularis	0.17	0.12	0.73	0.55	0.81	52.99
Potamyia flava	0.22	0.05	0.73	0.54	0.81	53.79
Chimarra beameri	0.01	0.24	0.72	0.55	0.8	54.59
Oxyethira aculea	0.04	0.24	0.71	0.56	0.79	55.38
Nectopsyche pavida	0.18	0.12	0.71	0.56	0.78	56.16
Oecetis osteni	0.27	0	0.69	0.58	0.77	56.93
Protoptila alexanderi	0.04	0.21	0.69	0.52	0.76	57.69
Hydroptila melia	0.03	0.21	0.68	0.52	0.75	58.45
Hydropsyche orris	0.14	0.1	0.65	0.49	0.72	59.16
Hydroptila quinola	0.25	0	0.64	0.55	0.71	59.87
Oxyethira novasota	0.25	0	0.63	0.54	0.7	60.58
Polyplectropus charlsei	0.03	0.21	0.62	0.51	0.69	61.26
Hydroptila scolops	0.21	0	0.62	0.49	0.68	61.95
Oxyethira parce	0	0.21	0.61	0.49	0.68	62.63
Ochrotrichia felipe	0	0.21	0.59	0.49	0.66	63.28
Cheumatopsyche burksi	0.21	0	0.59	0.49	0.65	63.94
Hydroptila modica	0.01	0.21	0.58	0.51	0.65	64.58

Nyctiophylax serratus	0.22	0.02	0.58	0.53	0.64	65.22
Groups OUACHITA & GREAT PLAINS						
Average dissimilarity = 91.94						
PROVINCE	OUACHITA	GREAT PLAINS				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Polycentropus centralis	0.76	0.07	2.33	1.46	2.53	2.53
Chimarra feria	0.62	0.05	1.99	1.16	2.16	4.69
Chimarra obscura	0.73	0.52	1.64	0.92	1.79	6.48
Cheumatopsyche comis	0.02	0.52	1.6	0.98	1.74	8.22
Oecetis inconspicua	0.44	0.45	1.58	0.94	1.72	9.94
Oecetis avara	0.2	0.5	1.58	0.94	1.72	11.66
Ochrotrichia tarsalis	0.02	0.5	1.57	0.93	1.71	13.37
Cernotina calcea	0.16	0.45	1.51	0.88	1.64	15.01
Cheumatopsyche analis	0.38	0.31	1.49	0.86	1.62	16.62
Polycentropus picana	0	0.48	1.47	0.9	1.6	18.22
Helicopsyche limnella	0.45	0	1.46	0.87	1.59	19.81
Helicopsyche borealis	0.09	0.43	1.4	0.84	1.53	21.34
Nyctiophylax affinis	0.36	0.29	1.39	0.84	1.51	22.85
Smicridea fasciatella	0	0.43	1.31	0.82	1.43	24.28
Rhyacophila kiamichi	0.4	0	1.28	0.77	1.4	25.68
Diplectrona modesta	0.4	0	1.26	0.78	1.37	27.05
Hydropsyche betteni	0.4	0	1.23	0.78	1.33	28.38
Oxyethira azteca	0	0.38	1.18	0.74	1.29	29.67
Polyplectropus santiago	0	0.38	1.16	0.74	1.26	30.93
Cheumatopsyche campyla	0.13	0.29	1.08	0.68	1.18	32.1
Polycentropus harpi	0.33	0.02	1.05	0.68	1.15	33.25
Hydroptila angusta	0	0.33	1.05	0.67	1.14	34.39
Cheumatopsyche oxa	0.33	0	1.01	0.67	1.1	35.49
Hydroptila protera	0	0.33	1.01	0.67	1.1	36.6
Psychomyia flavida	0.31	0	0.98	0.64	1.07	37.67
Oxyethira pallida	0.05	0.29	0.98	0.64	1.07	38.74
Hydroptila hamata	0.2	0.17	0.98	0.63	1.07	39.8
Wormaldia moesta	0.33	0	0.97	0.66	1.05	40.86
Hydroptila icona	0	0.33	0.96	0.67	1.05	41.9
Agapetus medicus	0.31	0	0.96	0.64	1.04	42.95
Ochrotrichia capitana	0	0.31	0.94	0.63	1.03	43.97
Chimarra angustipennis	0	0.31	0.92	0.64	1	44.97
Cheumatopsyche robisoni	0.29	0	0.89	0.62	0.97	45.94
Nectopsyche gracilis	0	0.31	0.89	0.64	0.96	46.91
Marilia flexuosa	0	0.26	0.86	0.57	0.93	47.84
Ceraclea maculata	0.13	0.19	0.81	0.58	0.88	48.72
Oxyethira ulmeri	0	0.29	0.8	0.61	0.87	49.59
Orthotrichia cristata	0.02	0.24	0.79	0.55	0.86	50.45
Rhyacophila glaberrima	0.25	0	0.77	0.57	0.84	51.28

Chimarra beameri	0	0.24	0.74	0.54	0.81	52.09
Oecetis ditissa	0.22	0.05	0.74	0.54	0.8	52.89
Oxyethira aculea	0	0.24	0.72	0.53	0.78	53.67
Nectopsyche exquisita	0.22	0	0.71	0.5	0.77	54.45
Ceraclea tarsipunctata	0.22	0	0.7	0.51	0.76	55.21
Hydropsyche simulans	0.02	0.24	0.7	0.55	0.76	55.98
Hydroptila melia	0	0.21	0.68	0.51	0.74	56.72
Oecetis nocturna	0.22	0	0.68	0.5	0.74	57.45
Protoptila alexanderi	0	0.21	0.67	0.49	0.73	58.18
Oxyethira parce	0	0.21	0.65	0.49	0.71	58.89
Cheumatopsyche minuscula	0.22	0	0.65	0.5	0.71	59.6
Agrypnia vestita	0.22	0	0.64	0.51	0.7	60.3
Nectopsyche pavida	0.13	0.12	0.64	0.49	0.7	61
Ochrotrichia felipe	0	0.21	0.64	0.49	0.69	61.69
Hydroptila grandiosa	0.2	0	0.64	0.48	0.69	62.38
Ochrotrichia anisca	0.2	0	0.63	0.47	0.69	63.07
Agapetus illini	0.2	0	0.6	0.47	0.66	63.73
Polyplectropus charlsei	0	0.21	0.6	0.49	0.65	64.38
Triaenodes ignitus	0.13	0.1	0.6	0.48	0.65	65.03

Groups OZARK PLATEAUS & GREAT PLAINS
Average dissimilarity = 90.22

PROVINCE	OZARK PLATEAUS	GREAT PLAINS				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chimarra obscura	0.72	0.52	1.57	0.91	1.74	1.74
Helicopsyche borealis	0.44	0.43	1.53	0.91	1.7	3.44
Cheumatopsyche comis	0	0.52	1.53	0.97	1.7	5.13
Oecetis avara	0.24	0.5	1.52	0.92	1.69	6.82
Ochrotrichia tarsalis	0.08	0.5	1.51	0.92	1.67	8.49
Cheumatopsyche analis	0.48	0.31	1.5	0.9	1.66	10.15
Oecetis inconspicua	0.4	0.45	1.48	0.91	1.64	11.8
Cernotina calcea	0.24	0.45	1.45	0.88	1.61	13.41
Polycentropus picana	0	0.48	1.41	0.88	1.56	14.97
Potamyia flava	0.44	0.05	1.33	0.82	1.47	16.44
Smicridea fasciatella	0	0.43	1.26	0.81	1.39	17.83
Cheumatopsyche campyla	0.32	0.29	1.25	0.79	1.39	19.22
Psychomyia flavida	0.4	0	1.24	0.76	1.37	20.59
Hydroptila hamata	0.36	0.17	1.22	0.77	1.36	21.95
Ochrotrichia anisca	0.4	0	1.21	0.76	1.34	23.29
Agapetus illini	0.4	0	1.21	0.76	1.34	24.64
Cheumatopsyche minuscula	0.4	0	1.19	0.75	1.32	25.95
Polycentropus centralis	0.4	0.07	1.18	0.78	1.3	27.26
Hydropsyche simulans	0.28	0.24	1.17	0.73	1.29	28.55
Oxyethira azteca	0	0.38	1.13	0.73	1.25	29.81
Ceraclea cancellata	0.36	0	1.13	0.71	1.25	31.05

Polyplectropus santiago	0	0.38	1.11	0.73	1.23	32.28
Nyctiophylax affinis	0.2	0.29	1.06	0.71	1.17	33.45
Cheumatopsyche oxa	0.4	0	1.05	0.75	1.17	34.62
Oxyethira pallida	0.12	0.29	1.04	0.67	1.15	35.77
Ceraclea maculata	0.24	0.19	1.03	0.67	1.15	36.92
Chimarra feria	0.32	0.05	1.03	0.65	1.14	38.05
Marilia flexuosa	0.12	0.26	1.01	0.65	1.12	39.18
Hydroptila angusta	0	0.33	1	0.66	1.11	40.29
Nectopsyche pavida	0.28	0.12	0.98	0.65	1.09	41.37
Ceraclea transversa	0.36	0	0.98	0.69	1.08	42.46
Hydroptila protera	0	0.33	0.97	0.66	1.08	43.53
Hydroptila icona	0	0.33	0.92	0.66	1.02	44.56
Ochrotrichia capitana	0	0.31	0.9	0.62	1	45.56
Chimarra angustipennis	0	0.31	0.88	0.63	0.97	46.53
Nectopsyche gracilis	0	0.31	0.85	0.63	0.94	47.47
Hydroptila perdita	0.32	0	0.82	0.63	0.91	48.38
Chimarra aterrima	0.28	0	0.8	0.58	0.89	49.27
Oxyethira ulmeri	0	0.29	0.76	0.6	0.85	50.12
Hydroptila virgata	0.28	0	0.76	0.58	0.84	50.96
Orthotrichia cristata	0	0.24	0.73	0.53	0.81	51.77
Ceraclea tarsipunctata	0.24	0	0.72	0.53	0.8	52.57
Paduniella nearctica	0.24	0	0.71	0.53	0.79	53.36
Chimarra beameri	0	0.24	0.71	0.54	0.79	54.14
Ceraclea ancylus	0.2	0	0.7	0.49	0.78	54.92
Oxyethira aculea	0	0.24	0.69	0.53	0.76	55.69
Rhyacophila kiamichi	0.24	0	0.65	0.52	0.72	56.41
Hydroptila melia	0	0.21	0.65	0.5	0.72	57.13
Protoptila alexanderi	0	0.21	0.64	0.49	0.71	57.85
Plectrocnemia cinerea	0.24	0.05	0.63	0.57	0.7	58.55
Oxyethira parce	0	0.21	0.63	0.49	0.69	59.24
Hydropsyche scalaris	0.24	0	0.61	0.52	0.68	59.92
Ochrotrichia felipe	0	0.21	0.61	0.49	0.67	60.6
Triaenodes ignitus	0.12	0.1	0.59	0.47	0.65	61.25
Polyplectropus charlsei	0	0.21	0.58	0.49	0.64	61.89
Hydroptila modica	0	0.21	0.56	0.5	0.62	62.51
Nectopsyche exquisita	0.2	0	0.55	0.46	0.61	63.12
Hydroptila ajax	0	0.17	0.54	0.43	0.6	63.72
Oecetis ditissa	0.16	0.05	0.54	0.46	0.59	64.32
Hydropsyche incommoda	0.2	0	0.53	0.46	0.59	64.91
Mayatrichia ponta	0	0.19	0.52	0.46	0.58	65.49
Groups CENTRAL LOWLAND &	GREAT PLAINS					
Average dissimilarity = 80.24						
PROVINCE	CENTRAL LOWLAND	GREAT PLAINS				

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Triaenodes tardus	0.8	0.07	2.4	1.57	2.99	2.99
Triaenodes injustus	0.7	0.1	2.03	1.28	2.53	5.52
Potamyia flava	0.7	0.05	1.96	1.33	2.44	7.97
Cheumatopsyche campyla	0.77	0.29	1.91	1.17	2.38	10.35
Hydropsyche bidens	0.63	0.12	1.87	1.13	2.33	12.68
Cheumatopsyche analis	0.77	0.31	1.82	1.13	2.27	14.95
Oecetis inconspicua	0.97	0.45	1.8	1.03	2.24	17.19
Oecetis cinerascens	0.63	0.14	1.79	1.12	2.23	19.42
Cheumatopsyche lasia	0.57	0.02	1.62	1.06	2.02	21.44
Oecetis avara	0.7	0.5	1.57	0.94	1.96	23.4
Hydropsyche simulans	0.53	0.24	1.55	0.96	1.94	25.33
Chimarra obscura	0.8	0.52	1.51	0.92	1.88	27.22
Helicopsyche borealis	0.47	0.43	1.5	0.93	1.86	29.08
Ochrotrichia tarsalis	0.33	0.5	1.49	0.94	1.86	30.94
Cheumatopsyche comis	0	0.52	1.49	0.98	1.85	32.79
Cernotina calcea	0.37	0.45	1.47	0.92	1.83	34.62
Smicridea fasciatella	0.33	0.43	1.39	0.9	1.73	36.35
Polycentropus picana	0	0.48	1.37	0.89	1.71	38.05
Hydropsyche orris	0.47	0.1	1.35	0.89	1.69	39.74
Ceraclea maculata	0.43	0.19	1.35	0.87	1.68	41.42
Cyrnellus fraternus	0.43	0.1	1.32	0.85	1.64	43.06
Nyctiophylax affinis	0.37	0.29	1.29	0.84	1.61	44.67
Hydroptila angusta	0.23	0.33	1.2	0.79	1.49	46.16
Oxyethira azteca	0.1	0.38	1.16	0.78	1.45	47.61
Orthotrichia aegerfasciella	0.37	0.1	1.16	0.77	1.44	49.06
Oxyethira pallida	0.27	0.29	1.15	0.78	1.44	50.49
Polyplectropus santiago	0	0.38	1.08	0.74	1.34	51.84
Oecetis ditissa	0.33	0.05	1.08	0.7	1.34	53.18
Hydroptila ajax	0.27	0.17	1.01	0.69	1.26	54.44
Hydroptila protera	0.03	0.33	0.97	0.68	1.21	55.64
Orthotrichia cristata	0.17	0.24	0.95	0.66	1.18	56.83
Hydroptila icona	0.03	0.33	0.92	0.69	1.15	57.98
Ochrotrichia capitana	0	0.31	0.88	0.63	1.09	59.07
Chimarra angustipennis	0	0.31	0.85	0.64	1.06	60.13
Nectopsyche gracilis	0	0.31	0.83	0.64	1.03	61.16
Chimarra feria	0.27	0.05	0.83	0.61	1.03	62.19
Hydroptila hamata	0.17	0.17	0.8	0.6	1	63.19
Marilia flexuosa	0	0.26	0.79	0.57	0.99	64.18
Hydropsyche scalaris	0.3	0	0.77	0.63	0.96	65.15
Groups COASTAL PLAIN & BASIN AND RANGE						
Average dissimilarity = 99.09						
PROVINCE	COASTAL PLAIN	BASIN AND RANGE				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%

Hydroptila arctia	0	0.88	2.95	2.17	2.97	2.97
Ochrotrichia dactylophora	0	0.88	2.88	2.19	2.91	5.89
Oecetis inconspicua	0.7	0	2.18	1.39	2.2	8.09
Chimarra ridleyi	0	0.63	1.98	1.21	2	10.09
Helicopsyche mexicana	0	0.5	1.76	0.95	1.78	11.87
Ochrotrichia rothi	0	0.5	1.69	0.94	1.7	13.57
Polycentropus halidus	0	0.5	1.68	0.95	1.69	15.26
Marilia flexuosa	0	0.5	1.63	0.94	1.64	16.91
Helicopsyche borealis	0.05	0.5	1.59	0.95	1.6	18.51
Ceraclea maculata	0.49	0	1.52	0.94	1.54	20.05
Cyrnellus fraternus	0.45	0	1.5	0.88	1.52	21.57
Cheumatopsyche analis	0.42	0	1.3	0.8	1.31	22.87
Oecetis persimilis	0.44	0	1.29	0.84	1.3	24.18
Nectopsyche candida	0.42	0	1.28	0.79	1.29	25.46
Cheumatopsyche arizonensis	0	0.38	1.25	0.74	1.26	26.72
Wormaldia arizonensis	0	0.38	1.24	0.73	1.25	27.97
Phylloicus aeneus	0	0.38	1.22	0.74	1.23	29.2
Cheumatopsyche pinula	0	0.38	1.21	0.75	1.22	30.43
Cernotina calcea	0.36	0	1.19	0.73	1.21	31.63
Hydroptila waubesiana	0.36	0	1.14	0.71	1.15	32.78
Oecetis nocturna	0.39	0	1.12	0.75	1.13	33.91
Oecetis ditissa	0.35	0	1.09	0.69	1.1	35.01
Chimarra obscura	0.31	0	0.97	0.63	0.98	35.99
Cheumatopsyche pasella	0.34	0	0.97	0.68	0.97	36.97
Lepidostoma knulli	0	0.25	0.92	0.56	0.93	37.89
Limnephilus frijole	0	0.25	0.92	0.56	0.93	38.82
Oecetis cinerascens	0.3	0	0.92	0.62	0.93	39.75
Oecetis avara	0.19	0.13	0.91	0.59	0.91	40.66
Macrostemum carolina	0.29	0	0.89	0.6	0.9	41.56
Oxyethira janella	0.29	0	0.89	0.6	0.9	42.46
Oxyethira dualis	0	0.25	0.87	0.56	0.88	43.34
Hydroptila hamata	0.03	0.25	0.87	0.58	0.88	44.21
Ochrotrichia arizonica	0	0.25	0.85	0.56	0.86	45.08
Oecetis disjuncta	0	0.25	0.84	0.56	0.85	45.92
Culoptila cantha	0.05	0.25	0.83	0.6	0.83	46.76
Hydropsyche mississippiensis	0.29	0	0.83	0.61	0.83	47.59
Hydropsyche rossi	0.26	0	0.82	0.56	0.83	48.42
Hydropsyche occidentalis	0	0.25	0.82	0.56	0.83	49.25
Hydropsyche auricolor	0	0.25	0.81	0.56	0.82	50.07
Triaenodes ignitus	0.3	0	0.8	0.62	0.81	50.88
Chimarra parasocia	0.27	0	0.8	0.59	0.81	51.69
Phylocentropus placidus	0.29	0	0.8	0.6	0.8	52.5
Cheumatopsyche enonis	0	0.25	0.8	0.56	0.8	53.3
Chimarra utahensis	0	0.25	0.8	0.56	0.8	54.1

Chimarra angustipennis	0.03	0.25	0.79	0.57	0.8	54.9
Hydropsyche orris	0.14	0.13	0.78	0.53	0.79	55.69
Orthotrichia aegerfasciella	0.23	0	0.78	0.52	0.78	56.47
Leucotrichia limpia	0	0.25	0.77	0.55	0.78	57.25
Oecetis osteni	0.27	0	0.74	0.58	0.75	58
Hydroptila quinola	0.25	0	0.69	0.55	0.7	58.69
Oxyethira novasota	0.25	0	0.68	0.54	0.69	59.38
Potamyia flava	0.22	0	0.68	0.51	0.69	60.07
Mayatrichia ayama	0.23	0	0.68	0.53	0.69	60.76
Cheumatopsyche lasia	0.13	0.13	0.67	0.52	0.68	61.44
Smicridea fasciatella	0.13	0.13	0.67	0.52	0.68	62.11
Hydroptila scolops	0.21	0	0.67	0.49	0.68	62.79
Cheumatopsyche burksi	0.21	0	0.64	0.49	0.64	63.43
Neotrichia minutisimella	0.13	0.13	0.62	0.51	0.62	64.06
Hydroptila lloganae	0.21	0	0.6	0.48	0.6	64.66
Nyctiophylax serratus	0.22	0	0.58	0.51	0.58	65.24
Groups OUACHITA & BASIN AND RANGE						
Average dissimilarity = 99.14						
PROVINCE	OUACHITA	BASIN AND RANGE				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hydroptila arctia	0	0.88	3.19	2.27	3.21	3.21
Ochrotrichia dactylophora	0	0.88	3.11	2.29	3.14	6.36
Polycentropus centralis	0.76	0	2.66	1.64	2.68	9.04
Chimarra obscura	0.73	0	2.61	1.51	2.64	11.67
Chimarra feria	0.62	0	2.22	1.21	2.24	13.91
Chimarra ridleyi	0	0.63	2.14	1.23	2.16	16.07
Helicopsyche mexicana	0	0.5	1.91	0.96	1.92	17.99
Ochrotrichia rothi	0	0.5	1.83	0.95	1.84	19.83
Polycentropus halidus	0	0.5	1.81	0.97	1.83	21.66
Marilia flexuosa	0	0.5	1.76	0.95	1.77	23.43
Helicopsyche borealis	0.09	0.5	1.72	0.96	1.73	25.17
Helicopsyche limnella	0.45	0	1.6	0.88	1.61	26.78
Oecetis inconspicua	0.44	0	1.44	0.84	1.45	28.23
Rhyacophila kiamichi	0.4	0	1.4	0.78	1.42	29.65
Diplectrona modesta	0.4	0	1.37	0.79	1.39	31.03
Cheumatopsyche arizonensis	0	0.38	1.34	0.75	1.36	32.39
Cheumatopsyche analis	0.38	0	1.34	0.75	1.36	33.75
Wormaldia arizonensis	0	0.38	1.34	0.74	1.35	35.1
Hydropsyche betteni	0.4	0	1.34	0.79	1.35	36.44
Phylloicus aeneus	0	0.38	1.32	0.74	1.33	37.77
Cheumatopsyche pinula	0	0.38	1.31	0.76	1.32	39.09
Hydroptila hamata	0.2	0.25	1.25	0.71	1.26	40.35
Nyctiophylax affinis	0.36	0	1.21	0.72	1.22	41.57
Polycentropus harpi	0.33	0	1.11	0.68	1.12	42.69

Cheumatopsyche oxa	0.33	0	1.11	0.68	1.12	43.81
Psychomyia flavida	0.31	0	1.08	0.65	1.08	44.89
Wormaldia moesta	0.33	0	1.05	0.67	1.06	45.95
Agapetus medicus	0.31	0	1.05	0.65	1.06	47.01
Lepidostoma knulli	0	0.25	1	0.56	1.01	48.02
Limnephilus frijole	0	0.25	1	0.56	1.01	49.02
Oecetis avara	0.2	0.13	1	0.6	1	50.03
Cheumatopsyche robisoni	0.29	0	0.97	0.62	0.98	51.01
Oxyethira dualis	0	0.25	0.94	0.56	0.95	51.96
Ochrotrichia arizonica	0	0.25	0.92	0.56	0.93	52.89
Oecetis disjuncta	0	0.25	0.91	0.56	0.92	53.81
Hydropsyche occidentalis	0	0.25	0.89	0.57	0.9	54.7
Hydropsyche auricolor	0	0.25	0.87	0.57	0.88	55.58
Cheumatopsyche enonis	0	0.25	0.86	0.57	0.86	56.45
Chimarra utahensis	0	0.25	0.86	0.57	0.86	57.31
Rhyacophila glaberrima	0.25	0	0.84	0.57	0.85	58.16
Leucotrichia limpia	0	0.25	0.83	0.56	0.84	58.99
Culoptila cantha	0	0.25	0.79	0.56	0.8	59.8
Nectopsyche exquisita	0.22	0	0.78	0.51	0.79	60.58
Chimarra angustipennis	0	0.25	0.78	0.56	0.79	61.37
Ceraclea tarsipunctata	0.22	0	0.77	0.51	0.78	62.14
Oecetis nocturna	0.22	0	0.74	0.51	0.75	62.89
Oecetis ditissa	0.22	0	0.71	0.5	0.72	63.61
Cheumatopsyche minuscula	0.22	0	0.71	0.51	0.71	64.32
Agrypnia vestita	0.22	0	0.7	0.51	0.71	65.03
Groups OZARK PLATEAUS & BASIN AND RANGE						
Average dissimilarity = 97.28						
PROVINCE	OZARK PLATEAUS	BASIN AND RANGE				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hydroptila arctia	0	0.88	3.04	2.13	3.12	3.12
Ochrotrichia dactylophora	0	0.88	2.97	2.15	3.05	6.18
Chimarra obscura	0.72	0	2.45	1.45	2.52	8.7
Chimarra ridleyi	0	0.63	2.04	1.2	2.1	10.8
Helicopsyche mexicana	0	0.5	1.82	0.94	1.87	12.66
Ochrotrichia rothi	0	0.5	1.74	0.93	1.79	14.45
Polycentropus halidus	0	0.5	1.73	0.94	1.78	16.23
Helicopsyche borealis	0.44	0.5	1.71	0.94	1.75	17.99
Marilia flexuosa	0.12	0.5	1.69	0.93	1.74	19.72
Cheumatopsyche analis	0.48	0	1.5	0.88	1.55	21.27
Hydroptila hamata	0.36	0.25	1.43	0.82	1.47	22.74
Potamyia flava	0.44	0	1.41	0.82	1.45	24.19
Psychomyia flavida	0.4	0	1.35	0.76	1.39	25.58
Agapetus illini	0.4	0	1.32	0.76	1.36	26.94
Ochrotrichia anisca	0.4	0	1.32	0.77	1.36	28.3

Cheumatopsyche minuscula	0.4	0	1.3	0.76	1.33	29.63
Cheumatopsyche arizonensis	0	0.38	1.28	0.74	1.32	30.95
Wormaldia arizonensis	0	0.38	1.28	0.73	1.31	32.26
Phylloicus aeneus	0	0.38	1.26	0.73	1.29	33.55
Cheumatopsyche pinula	0	0.38	1.25	0.74	1.28	34.84
Ceraclea cancellata	0.36	0	1.23	0.72	1.26	36.1
Polycentropus centralis	0.4	0	1.21	0.76	1.24	37.35
Oecetis inconspicua	0.4	0	1.2	0.75	1.23	38.58
Cheumatopsyche oxa	0.4	0	1.14	0.75	1.17	39.75
Oecetis avara	0.24	0.13	1.09	0.63	1.12	40.87
Ceraclea transversa	0.36	0	1.06	0.69	1.09	41.96
Chimarra feria	0.32	0	1.05	0.63	1.08	43.04
Oxyethira dualis	0.04	0.25	0.96	0.58	0.99	44.03
Hydropsyche simulans	0.28	0	0.96	0.59	0.99	45.02
Lepidostoma knulli	0	0.25	0.95	0.55	0.98	46
Limnephilus frijole	0	0.25	0.95	0.55	0.98	46.97
Cheumatopsyche campyla	0.32	0	0.94	0.64	0.97	47.94
Nectopsyche pavida	0.28	0	0.9	0.57	0.92	48.86
Hydroptila perdita	0.32	0	0.89	0.63	0.91	49.77
Ochrotrichia arizonica	0	0.25	0.88	0.55	0.91	50.68
Chimarra aterrima	0.28	0	0.87	0.59	0.9	51.58
Oecetis disjuncta	0	0.25	0.87	0.55	0.89	52.47
Hydropsyche occidentalis	0	0.25	0.85	0.56	0.87	53.34
Hydropsyche auricolor	0	0.25	0.83	0.56	0.86	54.2
Hydroptila virgata	0.28	0	0.82	0.58	0.84	55.04
Cheumatopsyche enonis	0	0.25	0.82	0.56	0.84	55.88
Chimarra utahensis	0	0.25	0.82	0.56	0.84	56.72
Ceraclea maculata	0.24	0	0.81	0.54	0.83	57.55
Leucotrichia limpia	0	0.25	0.79	0.55	0.81	58.36
Ceraclea tarsipunctata	0.24	0	0.79	0.53	0.81	59.17
Paduniella nearctica	0.24	0	0.77	0.53	0.8	59.97
Ceraclea ancylus	0.2	0	0.77	0.49	0.8	60.76
Culoptila cantha	0	0.25	0.76	0.56	0.78	61.55
Chimarra angustipennis	0	0.25	0.75	0.56	0.77	62.31
Rhyacophila kiamichi	0.24	0	0.71	0.53	0.73	63.04
Cernotina calcea	0.24	0	0.67	0.53	0.69	63.73
Hydropsyche scalaris	0.24	0	0.66	0.52	0.68	64.41
Hydropsyche orris	0.08	0.13	0.65	0.46	0.67	65.09
Groups CENTRAL LOWLAND & BASIN AND RANGE Average dissimilarity = 96.69						
PROVINCE	CENTRAL LOWLAND	BASIN AND RANGE				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oecetis inconspicua	0.97	0	3.26	3.46	3.37	3.37

Hydroptila arctia	0	0.88	2.93	2.22	3.03	6.41
Ochrotrichia dactylophora	0	0.88	2.87	2.24	2.97	9.38
Triaenodes tardus	0.8	0	2.77	1.81	2.87	12.24
Cheumatopsyche campyla	0.77	0	2.59	1.65	2.68	14.92
Chimarra obscura	0.8	0	2.51	1.8	2.59	17.52
Cheumatopsyche analis	0.77	0	2.47	1.63	2.56	20.07
Triaenodes injustus	0.7	0	2.33	1.41	2.41	22.48
Potamyia flava	0.7	0	2.19	1.41	2.26	24.74
Oecetis avara	0.7	0.13	2.15	1.27	2.22	26.96
Hydropsyche bidens	0.63	0	2.14	1.23	2.22	29.18
Oecetis cinerascens	0.63	0	2.05	1.22	2.12	31.3
Chimarra ridleyi	0	0.63	1.98	1.22	2.04	33.34
Helicopsyche mexicana	0	0.5	1.75	0.95	1.81	35.15
Cheumatopsyche lasia	0.57	0.13	1.74	1.06	1.8	36.95
Hydropsyche simulans	0.53	0	1.72	1	1.77	38.72
Ochrotrichia rothi	0	0.5	1.68	0.94	1.74	40.46
Polycentropus halidus	0	0.5	1.67	0.96	1.73	42.19
Helicopsyche borealis	0.47	0.5	1.65	0.95	1.71	43.9
Marilia flexuosa	0	0.5	1.62	0.95	1.68	45.57
Hydropsyche orris	0.47	0.13	1.49	0.91	1.54	47.11
Cyrnellus fraternus	0.43	0	1.38	0.84	1.43	48.54
Ceraclea maculata	0.43	0	1.36	0.84	1.4	49.94
Cheumatopsyche arizonensis	0	0.38	1.24	0.75	1.28	51.23
Wormaldia arizonensis	0	0.38	1.23	0.74	1.27	52.5
Phylloicus aeneus	0	0.38	1.21	0.74	1.26	53.76
Cheumatopsyche pinula	0	0.38	1.21	0.75	1.25	55.01
Orthotrichia aegerfasciella	0.37	0	1.16	0.74	1.2	56.21
Cernotina calcea	0.37	0	1.13	0.74	1.17	57.38
Oecetis ditissa	0.33	0	1.13	0.68	1.17	58.55
Nyctiophylax affinis	0.37	0	1.12	0.74	1.16	59.71
Smicridea fasciatella	0.33	0.13	1.07	0.75	1.11	60.82
Hydroptila hamata	0.17	0.25	1.06	0.68	1.1	61.92
Lepidostoma knulli	0	0.25	0.91	0.56	0.94	62.86
Limnephilus frijole	0	0.25	0.91	0.56	0.94	63.8
Ochrotrichia tarsalis	0.33	0	0.9	0.69	0.93	64.74
Oxyethira dualis	0	0.25	0.86	0.56	0.89	65.63

Groups GREAT PLAINS & BASIN AND RANGE
Average dissimilarity = 93.34

PROVINCE	GREAT PLAINS	BASIN AND RANGE				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ochrotrichia dactylophora	0	0.88	3.02	2.28	3.24	3.24
Hydroptila arctia	0.14	0.88	2.77	1.69	2.97	6.21
Chimarra ridleyi	0	0.63	2.08	1.23	2.22	8.43
Helicopsyche mexicana	0	0.5	1.85	0.96	1.98	10.41

Chimarra obscura	0.52	0	1.78	1	1.91	12.31
Ochrotrichia rothi	0	0.5	1.77	0.95	1.9	14.21
Polycentropus halidus	0.02	0.5	1.76	0.96	1.89	16.1
Helicopsyche borealis	0.43	0.5	1.73	0.96	1.86	17.95
Marilia flexuosa	0.26	0.5	1.73	0.95	1.86	19.81
Cheumatopsyche comis	0.52	0	1.69	1	1.81	21.62
Ochrotrichia tarsalis	0.5	0	1.67	0.95	1.78	23.41
Oecetis avara	0.5	0.13	1.65	0.95	1.77	25.18
Polycentropus picana	0.48	0	1.56	0.91	1.67	26.85
Cernotina calcea	0.45	0	1.53	0.87	1.64	28.49
Smicridea fasciatella	0.43	0.13	1.46	0.86	1.56	30.05
Oecetis inconspicua	0.45	0	1.42	0.87	1.52	31.58
Wormaldia arizonensis	0.05	0.38	1.35	0.76	1.45	33.02
Cheumatopsyche arizonensis	0.05	0.38	1.35	0.77	1.44	34.46
Phylloicus aeneus	0.07	0.38	1.34	0.77	1.44	35.9
Chimarra angustipennis	0.31	0.25	1.3	0.8	1.4	37.3
Cheumatopsyche pinula	0	0.38	1.27	0.75	1.36	38.66
Oxyethira azteca	0.38	0	1.25	0.75	1.34	40
Polyplectropus santiago	0.38	0	1.23	0.75	1.32	41.32
Hydroptila protera	0.33	0.13	1.21	0.74	1.29	42.61
Hydroptila icona	0.33	0.13	1.16	0.75	1.24	43.85
Hydroptila hamata	0.17	0.25	1.15	0.69	1.24	45.09
Ochrotrichia capitana	0.31	0.13	1.15	0.71	1.23	46.32
Hydroptila angusta	0.33	0	1.11	0.68	1.19	47.51
Cheumatopsyche analis	0.31	0	1.06	0.65	1.14	48.65
Oxyethira dualis	0.07	0.25	1.04	0.62	1.12	49.77
Oecetis disjuncta	0.07	0.25	1.02	0.61	1.1	50.87
Limnephilus frijole	0.02	0.25	1	0.58	1.08	51.94
Oxyethira pallida	0.29	0	0.98	0.62	1.05	52.99
Lepidostoma knulli	0	0.25	0.96	0.56	1.03	54.03
Oxyethira aculea	0.24	0.13	0.96	0.64	1.03	55.05
Cheumatopsyche campyla	0.29	0	0.96	0.61	1.02	56.08
Hydropsyche occidentalis	0.05	0.25	0.96	0.6	1.02	57.1
Nectopsyche gracilis	0.31	0	0.94	0.64	1	58.11
Leucotrichia limpia	0.1	0.25	0.93	0.63	1	59.11
Nyctiophylax affinis	0.29	0	0.92	0.6	0.99	60.1
Culoptila cantha	0.07	0.25	0.92	0.61	0.98	61.08
Ochrotrichia arizonica	0	0.25	0.9	0.56	0.96	62.04
Chimarra utahensis	0.02	0.25	0.88	0.58	0.95	62.99
Hydropsyche auricolor	0	0.25	0.85	0.56	0.91	63.89
Oxyethira ulmeri	0.29	0	0.84	0.61	0.9	64.79
Cheumatopsyche enonis	0	0.25	0.83	0.56	0.89	65.69

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